BLM - Colorado

COLORADO AIR RESOURCE MANAGEMENT MODELING STUDY (CARMMS)

Detailed Descriptions of Background, Emissions Inventories and Air Quality Modeling Methodologies for the Study

Draft

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1.0 INTRODUCTION

1.1 Background

The Bureau of Land Management (BLM) is in the process of developing new Resource Management Plans (RMPs) for several Field Offices in Colorado. The draft RMP for the Grand Junction Field Office (GJFO) was released in January 2013[1]. In May 2013, a draft RMP for the Dominguez-Escalante National Conservation Area (D-E NCA) was released[2]. The draft RMP for the Uncompahgre Field Office (UFO), the RMP revision for the Royal Gorge Field Office (RGFO), and the Roan Plateau Planning Area Supplemental Environmental Impact Statement (SEIS) are all in preparation. As part of these RMPs, BLM is estimating the air quality (AQ) and air quality related value (AQRV) due to the projected BLM-authorized mineral development activities. The analysis includes the cumulative AQ and AQRV impacts due to all Reasonable Foreseeable Development (RFD) sources in the region. In the past, individual RMPs have generally performed their own AQ/AQRV analysis for a long-term year (e.g., 20 years out) when the maximum RMP development is projected to occur. This has resulted in inefficiencies and potential inconsistencies in the RMP's AQ/AQRV analysis and a possibility for a failure to adequately assess the effects of cumulative development across all BLM planning areas on AQ/AQRV in the region. In addition, making emissions projections for such a long-term future year results in increased uncertainties and may create potential inconsistencies in the RMP planned and actual development activities. Thus, the BLM GJFO RMP Air Resource Management Plan (ARMP[3]) contains a commitment to perform a unified regional air quality modeling study to address the AQ/AQRV impacts due to development activities within the GJFO planning area as well as all of BLM Colorado's development activities for a short-term year ~10 years in the future.

To address this commitment, the BLM has contracted with Environmental Management Planning and Solutions Inc. (EMPSi), and their Subcontractors ENVIRON International Corporation (ENVIRON) and Carter Lake Consulting (CLC), to perform the Colorado Air Resource Management Modeling Study (CARMMS). The first step in the CARMMS air quality modeling was the development of a Photochemical Grid Model (PGM) and far-field dispersion Modeling Protocol (ENVIRON, Carter Lake and EMPSi, 2014) to address potential AQ and AQRV impacts due to BLM-authorized mineral development and other BLM-authorized activities in western Colorado and in particular the GJFO and other BLM FOs planning areas in Colorado. AQRVs include visibility, sulfur and nitrogen deposition and lake acid neutralizing capacity (ANC). The BLM Colorado State Office (COSO) convened an Interagency Air Quality Review Team (IAQRT) that consists of U.S. Environmental Protection Agency (EPA) Region 8, Colorado Department of Health and Environment (CDPHE) Air Pollution Control Division (APCD), National Park service (NPS), Fish and Wildlife Service (FWS) and United States Forest Service (USFS) to review and comment on the Modeling Protocol in accordance with the June 23, 2011 Memorandum of Understanding (MOU[4]) between the United States Department of Interior (USDOI), United States Department of Agriculture (USDA) and United

[1] http://www.blm.gov/co/st/en/fo/gjfo/rmp/rmp.html
[2] http://www.blm.gov/co/st/en/nca/denca/denca_rmp.html
[3] http://www.blm.gov/pgdata/etc/medialib/blm/co/field_offices/grand_junction_field/Draft_RMP/appdx.Par.47942.File.dat/ApdxG_Draft%20GJFO%20Air%20Plan_508.pdf
[4] http://www.epa.gov/compliance/resources/policies/nepa/air-quality-analyses-mou-2011.pdf

States Environmental Protection Agency (EPA) on procedures for assessing the air quality and AQRV impacts due to BLM-authorized oil and gas development activities.

1.2 Purpose

This document presents the preliminary 2021 modeling results for the CARMMS high oil and gas development scenario source apportionment modeling. Presented are the individual AQ and AQRV impacts due to oil and gas (O&G) development on Federal lands within 13 separate Colorado BLM planning areas as well as the combined assessment of O&G development on Federal as well as non-Federal lands as well as mining within the 13 Colorado BLM planning areas. The 2021 modeling results are also compared against National and State Ambient Air Quality Standards (NAAQS and SAAQS) throughout the 4 km modeling domain. The contributions of O&G development to AQ and AQRV at Class I and sensitive Class II areas are also presented and compared to PSD concentration increments and visibility and deposition thresholds of concern.

The CARMMS modeling was performed following procedures documented in a Modeling Protocol. A first draft CARMMS air assessment Modeling Protocol was prepared in August 2013. The BLM and their contractors presented the results of the first draft CARMMS Modeling Protocol to the IAQRT at the BLM COSO office in Denver on October 30, 2013. The IAQRT provided comments on the first draft Modeling Protocol that were incorporated into a draft final Modeling Protocol that was released in January 2014 (ENVIRON, CLC and EMPSi, 2014) along with a Response-to-Comments document that was also dated January 2014. Another meeting with the IAQRT was held at the BLM COSO office on February 28, 2014. IAQRT provided several comments that were addressed in a March 4, 2014 Response-to-Comments document and incorporated into this document.

1.3 Overview of Modeling Approach

CARMMS is using a photochemical grid model (PGM) to assess the AQ and AQRV impacts associated with BLM-authorized mineral development on Federal lands within BLM Colorado and the New Mexico Farmington District Planning Areas. CARMMS will not assess the near-source AQ impacts of the oil and gas and other development activities that will be addressed at the Project level in the future. The development of a PGM database is quite resources intensive. Thus, to the extent possible, CARMMS will leverage two studies that have or are developing PGM modeling databases for the western States:

1. The West-wide Jump-start Air Quality Modeling Study (WestJumpAQMS) has performed meteorological, emissions and air quality modeling using a 36 km CONUS, 12 km WESTUS and 4 km Intermountain West modeling domains for the 2008 calendar year. Details on the WestJumpAQMS modeling approach, the PGM 2008 base case modeling and model performance evaluation are available on the WestJumpAQMS website[5] and contained within the WestJumpAQMS Modeling Protocol (ENVIRON, Alpine and UNC, 2013a[6]) and final report (ENVIRON, Alpine and UNC, 2013b[7]).

[5] http://www.wrapair2.org/WestJumpAQMS.aspx
[6] http://www.wrapair2.org/pdf/WestJumpAQMS_Modeling_Protocol_and_Source%20Apportionment_Design_FinalMay.pdf
[7] http://www.wrapair2.org/pdf/WestJumpAQMS_FinRpt_Finalv2.pdf

2. The Three-State Air Quality Study (3SAQS) is using the WestJumpAQMS 2008 PGM modeling platform and is developing a new PGM modeling database for the western U.S. and the 2011 calendar year. 3SAQS is also developing 2011 and 2020 emission inventories. The 3SAQS 2011 modeling platform was not ready in time for the CARMMS preliminary modeling.

For CARMMS, WestJumpAQMS developed a stand-alone 2008 4 km CAMx PGM modeling database for the CARMMS 4 km modeling domain shown in Figure 1-1. Boundary Conditions (BCs) for the 4 km CARMMS domain were obtained from a CAMx 2008 36/12 km simulation conducted by WestJumpAQMS. WestJumpAQMS has conducted a model performance evaluation for the WRF 2008 36/12/4 km meteorological simulation and the CAMx 2008 base case simulation that are summarized for the CARMMS region in, respectively, Appendices A and B with more details available on the WestJumpAQMS website[8].

The CARMMS preliminary CAMx modeling of the CARMMS 4 km modeling domain (Figure 2-1) for a 2021 future year emission scenario using the 2008 WestJumpAQMS 2008 meteorological inputs involved the following activities:

- Develop a 2021 Future Year emissions scenario using the CARMMS estimates of oil and gas and other mineral development within the Colorado and northern New Mexico BLM planning areas and the 3SAQS 2020 emission estimates for all other source categories.
    - For O&G emissions in the western Colorado BLM Planning Areas, CARMMS developed emissions calculators with data specific to each area. BLM COSO provided 2021 oil and gas activity projections for a High, Low and Medium Development Scenarios.
    - 2021 mining emissions within western Colorado BLM Planning Areas were also estimated using CARMMS emissions calculators.
    - O&G emissions for eastern Colorado BLM Planning Areas were developed in a study for the BLM Royal Gorge Field Office (RGFO) and provided by the BLM COSO.
    - The CARMMS emissions calculators were adapted to estimate emissions for the Mancos Shale development area using information provided by the BLM New Mexico Farmington Field Office (FFO).
    - O&G emissions for the Uinta Basin that were developed for the Air Resource Management Study (ARMS) were provided by the BLM Utah State Office (UTSO).
    - O&G emissions for the Wyoming were based on recent future year emission developed for the BLM Wyoming State Office (WYSO) Continental Divide-Creston Draft EIS modeling.
    - O&G emissions for the remainder of the region were based on recent 2020 emission projections developed by the Three State Air Quality Study (3SAQS)
    - Future year anthropogenic emissions for the remainder of the source categories were based on a 2020 emissions inventory developed by EPA for the PM2.5 NAAQS rulemaking and updated by 3SAQS.
    - Future year emissions for biogenics, fires, windblown dust, sea salt and lightning were kept constant at 2008 levels and were based on the WestJumpAQMS.

[8] http://www.wrapair2.org/WestJumpAQMS.aspx

- The future year emissions were processed using the SMOKE emissions model to generate 2020/2021 emissions for the WestJumpAQMS 36/12 km domain and 4 km CARMS domain.
- Perform CAMx modeling for the 36/12 km domains and the 2020/2021 emissions scenario using the 2008 WestJumpAQMS modeling platform.
- Develop 2020/2021 Boundary Condition (BC) inputs for the CARMMS 4 km modeling domain using output from the 36/12 km CAMx model simulation for the 2020/2021 emissions scenario using the 2008 WestJumpAQMS 2008 meteorological inputs.
- Perform CAMx ozone and particulate matter source apportionment simulations for the 2021 Baseline emissions scenario and 4 km CARMMS modeling domain using the WestJumpAQMS 2008 modeling platform.
    - Post-process the CAMx 2021 4 km CARMMS domain output to obtain the separate AQ and AQRV impacts due to mineral development activities on Federal lands within each of the Colorado and the northern New Mexico BLM planning areas for 2021 High Development O&G emissions scenario; and
    - Post-process the CAMx 2021 output to obtain the cumulative AQ and AQRV impacts due to mineral development on Federal and non-Federal lands within all of the Colorado and the northern New Mexico BLM planning areas for the 2021 High Development O&G emissions scenario.
- Summarize the AQ and AQRV impacts of BLM-authorized oil and gas development on Federal lands within each BLM Colorado planning areas alone and cumulative impacts across all planning areas in a report.

1.4 Air Quality Standards and AQRV Thresholds

1.4.1 Federal and State Air Quality Standards and PSD Increments

EPA sets National Ambient Air Quality Standards (NAAQS) for six principal pollutants, which are called criteria air pollutants (CAPs). The CAPs are: ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), Particle Pollution (particulate matter with a mean aerodynamic diameter of less than or equal to 10 and 2.5 microns; PM_{10} and $PM_{2.5}$), sulfur dioxide (SO_2) and lead (Pb). States may also set their own ambient air quality standards, which must be as stringent as the NAAQS but may be more stringent.

Federal air quality regulations adopted and enforced by the States limit incremental emission increases to specific levels defined by the classification of air quality in an area. The Prevention of Significant Deterioration (PSD) Program is designed to limit the incremental increase of specific air pollutant concentrations above a legally defined baseline level. Incremental increases in PSD Class I areas are strictly limited, while increases allowed in Class II areas are less strict. PSD Class I and Class II increments are defined for NO_2, PM_{10}, $PM_{2.5}$ and SO_2.

Table 1-2 summarizes the NAAQS, the Colorado Ambient and Quality Standards (CAAQS) and the New Mexico Ambient Air Quality Standards (NMAAQS). PSD Class I and Class II increments are also shown in Table 1-2.

Table 1-2. Applicable National and State Ambient Air Quality Standards and PSD concentration increments.

Pollutant/Averaging Time	NAAQS	CAAQS[13]	NMAAQS[14]	PSD Class I Increment[1]	PSD Class II Increment[1]
CO					
1-hour[2]	35 ppm	--	13.1 ppm	--	--
8-hour[2]	9 ppm	--	8.7ppm	--	--
NO_2					
1-hour[3]	100 ppb	--	--	--	--
24-hour	--	--	0.10 ppm	--	--
Annual[4]	53 ppb	--	0.05 ppm	2.5	25
O_3					
8-hour[5]	0.075 ppm	--	--	--	--
PM_{10}					
24-hour[6]	150 µg/m^3	--	--	8	30
Annual[7]	--	--	--	4	17
$PM_{2.5}$					
24-hour[8]	35 µg/m^3	--	--	2	9
Annual[9]	12 µg/m^3	--	--	1	4
SO_2					
1-hour[10]	75 ppb	--	--		
3-hour[11]	0.5 ppm	700 µg/m^3	--	25	512
24-hour[12]	--	--	0.10 ppm	5	91
Annual[4]	--	--	0.02 ppm	2	20

1. The PSD demonstrations serve information purposes only and do not constitute a regulatory PSD increment consumption analysis.
2. No more than one exceedance per calendar year; for MAAQS - No more than one exceedance per consecutive 12 months
3. 98th percentile, averaged over 3 year; for MAAQS - not to be exceeded more than once over any 12 consecutive months
4. Annual mean not to be exceeded; for MAAQS - arithmetic average over any four consecutive quarters not to be exceeded
5. Fourth-highest daily maximum 8-hour ozone concentrations in a year, averaged over 3 years
6. Not to be exceeded more than once per calendar year on average over 3 years.
7. 3 year average of the arithmetic means over a calendar year
8. 98th percentile, averaged over 3 years
9. Annual mean, averaged over 3 years, NAAQS promulgated December 14, 2012
10. 99th percentile of daily maximum 1-hour concentrations in a year, averaged over 3 years
11. No more than one exceedance per calendar year (secondary NAAQS) and no more than one exceedance in 12 consecutive months (CAAQS)
12. For areas in New Mexico not within 3.5 miles of the Chino Mines Company
13. http://www.colorado.gov/cs/Satellite/CDPHE-Main/CBON/1251601911433
14. http://www.nmcpr.state.nm.us/nmac/parts/title20/20.002.0003.htm

1.4.2 Air Quality Related Value (AQRV) Thresholds

The impacts of each BLM FO authorized oil and gas and other activities as well as cumulative impacts of all activities together at Class I and sensitive Class II areas will be assessed for three AQRVs: visibility, deposition and acid neutralizing capacity (ANC). The June 23, 2011 MOU between EPA, USDOI and USDA states that the project and cumulative AQRV impacts at Class I and sensitive Class II areas should be calculated and compared against thresholds of concern defined by the Federal Land Manager (FLM) for the given Class I or sensitive Class II area in question. In the CARMMS first draft Modeling Protocol and at the October 30, 2013 meeting with the Interagency Air Quality Review Team (IAQRT) we presented the following threshold of concern for AQRVs in Class I and sensitive Class II areas and there were no disagreements in the comments received from the IAQRT:

- Visibility impacts for each planning area BLM-authorized oil and gas sources and cumulative sources will be assessed using the FLAG (2010) procedures that use the new IMPROVE equation, annual average natural visibility background and monthly relative humidity adjustment factors [f(RH)] (see section 4.6.1). The visibility impacts from mineral development on Federal lands within each separate BLM planning area will be compared against the 0.5 change in deciview haze index threshold of concern and any exceedances will be reported.
- Cumulative sources visibility impacts will be assessed using a new visibility approach and metrics being developed by the FLMs based on the regional haze rule visibility metrics for the best and worst 20% visibility days as discussed in Section 4.6.2.
- Acid deposition impacts due to mineral development on Federal lands within each separate BLM planning area BLM-authorized oil and gas sources and cumulative sources for annual total sulfur and total nitrogen deposition will be compared against the 0.005 kg/ha/yr Deposition Analysis Threshold (DAT) for the western states. Cumulative N and S deposition impacts will be compared to critical load values of 1.5 kg/ha/yr for total N deposition; and 3 kg/ha/yr for total S deposition (see Section 4.7) .
- The predicted annual deposition fluxes of sulfur and nitrogen at sensitive lake receptors will be used to estimate the change in ANC in accordance with the January 2000, USFS Rocky Mountain Region's Screening Methodology for Calculating ANC Change to High Elevation Lakes, User's Guide (USFS, 2000). The predicted changes in ANC will be compared with the USFS's Level of Acceptable Change (LAC) thresholds of 10% for lakes with ANC values greater than 25 µeq/l and 1 µeq/l for lakes with background ANC values of 25 µeq/l and less (see Section 4.8).

2.0 CARMMS DATABASE DEVELOPMENT

2.1 Modeling System

The CARMMS 2008 modeling database was based on the WestJumpAQMS so the same modeling system was adopted. The justification for the model selection is given in the CARMMS Modeling Protocol (ENVIRON, Cater Lake and EMPSi, 2014). Table 2-1 lists the main models selected for the BLM CARMMS modeling with a brief summary of the reasons for their selection as follows:

- The WRF meteorological model was selected because it contains more recent updates and features compared to the MM5 alternative that is no longer supported by its developer.
- The SMOKE emissions model is the most current and up-to-date emissions modeling system and has performance improvements over the alternatives.
- The MOVES on-road mobile emissions modeling system is the recommended modeling system by the EPA and has the most current on-road mobile source emissions data.
- The MEGAN biogenic emissions model has been updated by WRAP specifically for simulating biogenic emissions in the western states.
- The CAMx photochemical grid model (PGM) includes a source apportionment capability that is critically important for the CARMMS is not available in the current version of the CMAQ PGM alternative.

Table 2-1. Summary of models selected for the BLM CARMMS modeling.

Model Type	Selected Model
Meteorological Model	Weather Research Forecasting (WRF)
Emissions Model	Sparse Matrix Operator Kernel Emissions (SMOKE)
Emissions Model – On Road Sources	Motor Vehicle Emissions Simulator (MOVES)
Emissions Model – Biogenic Sources	Model for Emissions of Gases and Aerosols in Nature (MEGAN)
Photochemical Grid Model	Comprehensive Air-quality Model with extensions (CAMx)

2.2 Episode Selection

Since the CARMMS will need to address annual average air quality issues (e.g., $PM_{2.5}$) and deposition issues, a full year is selected for modeling. Due to computational requirements and resource constraints, a single meteorological baseline year will be modeled. The 2008 calendar year was selected for the CARMMS modeling because it satisfied the most episode selection criteria of recent years:

1. The entire 2008 calendar year includes a variety of meteorological conditions. The year appears to have higher than average photochemical production potential so was not an atypical low year for secondary ozone and PM formation.

2. 2008 had observed ozone and $PM_{2.5}$ concentrations that were close and even above the ozone and $PM_{2.5}$ Design Values in Colorado.

3. The 2008 year did not include any special study data in Colorado. Note that enhanced monitoring of the Front Range region and vicinity is being planned for the summer of 2014.

4. By modeling a full year (366 days) there should be sufficient number of days to calculated RRFs following EPA's guidance document (EPA, 2007).

5. The 2008 calendar year is already being model as part of the Denver ozone modeling and in the WestJumpAQMS and 3SAQS. In particular, the ability to leverage the CARMMS database development off of WestJumpAQMS is critical to the success of the study.

6. Ozone nonattainment areas under the March 2008 0.075 ppm 8-hour ozone NAAQS were designed using 2008-2010 observations, which includes the selected 2008 modeling period.

7. The 2008 calendar year includes both weekdays and weekend days.

8. Of the recent years, 2008 fulfills more of the episode selection criteria than other recent year.

2.3 CARMMS Modeling Domains

To leverage modeling data from other studies, the CARMMS will adopt the so-called RPO Lambert projection that uses a longitude/latitude origin at (-97, 40) and standard latitude parallels of 33 and 45 degrees. Figure 2-1 displays the 4 km modeling domain used in the CARMMS emissions and photochemical modeling. An initial 4 km modeling domain was identified by including all Class I areas for which any part of the Class I area is within 200 km of a western Colorado BLM Field Office planning area. The New Mexico State Office (NMSO) has indicated that they would like to include their Mancos Shale Oil development in the CARMMS modeling. The Mancos Shale Oil development area would be within the New Mexico BLM Farmington District Office area, but would primarily reside in San Juan County with portions potentially stretching into neighboring Rio Arriba, Sandoval and McKinley Counties. Thus, the CARMMS 4 km domain was extended southward to include all Class I areas within 200 km of these four New Mexico counties.

Figure 2-1 also shows the Class I areas throughout the domain that were analyzed for air quality and AQRV impacts. More details on the Class I and sensitive Class II areas where the air quality and AQRV impacts due to oil and gas and other activities within the BLM planning areas will be assessed is given in Chapter 4.

The CAMx vertical domain definitions will depend on the definition of the WRF vertical layer structure. WRF was run with 37 vertical levels (36 vertical layers using CAMx definition of layer thicknesses) from the surface up to 50 mb (~19-km high above mean sea level) (ENVIRON and Alpine, 2012[9]). The WRF model employs a terrain following coordinate system defined by pressure, using multiple layers that extend from the surface to 50 mb (approximately 19 km above mean sea level). CARMMS is adopting the same layer collapsing strategy as used by WestJumpAQMS whereby multiple WRF layers are combined into one CAMx layer to reduce the air quality model computational time. Table 2-2 displays the approach for collapsing the WRF 36 vertical layers to 25 vertical layers in CAMx for CARMMS and WestJumpAQMS. The WRF

[9] http://www.wrapair2.org/pdf/WestJumpAQMS_2008_Annual_WRF_Final_Report_February29_2012.pdf

layer collapsing scheme in Table 2-2 is collapsing two WRF layers into one CAMx/CMAQ layer for the lowest four layers in CAMx/CMAQ. In the past, the lowest layers of MM5/WRF were mapped directly into CAMx/CMAQ with no layer collapsing. However, in those applications the MM5/WRF layer 1 was much thicker (20-40 m) than used in this WRF application (12 m). Use of a 12 m lowest layer may trap emissions in a too shallow layer resulted in overstated surface concentrations. For example, NO_X emissions are caused by combustion so are buoyant and have plume rise that in reality could take them out of the first layer if it is defined too shallow.

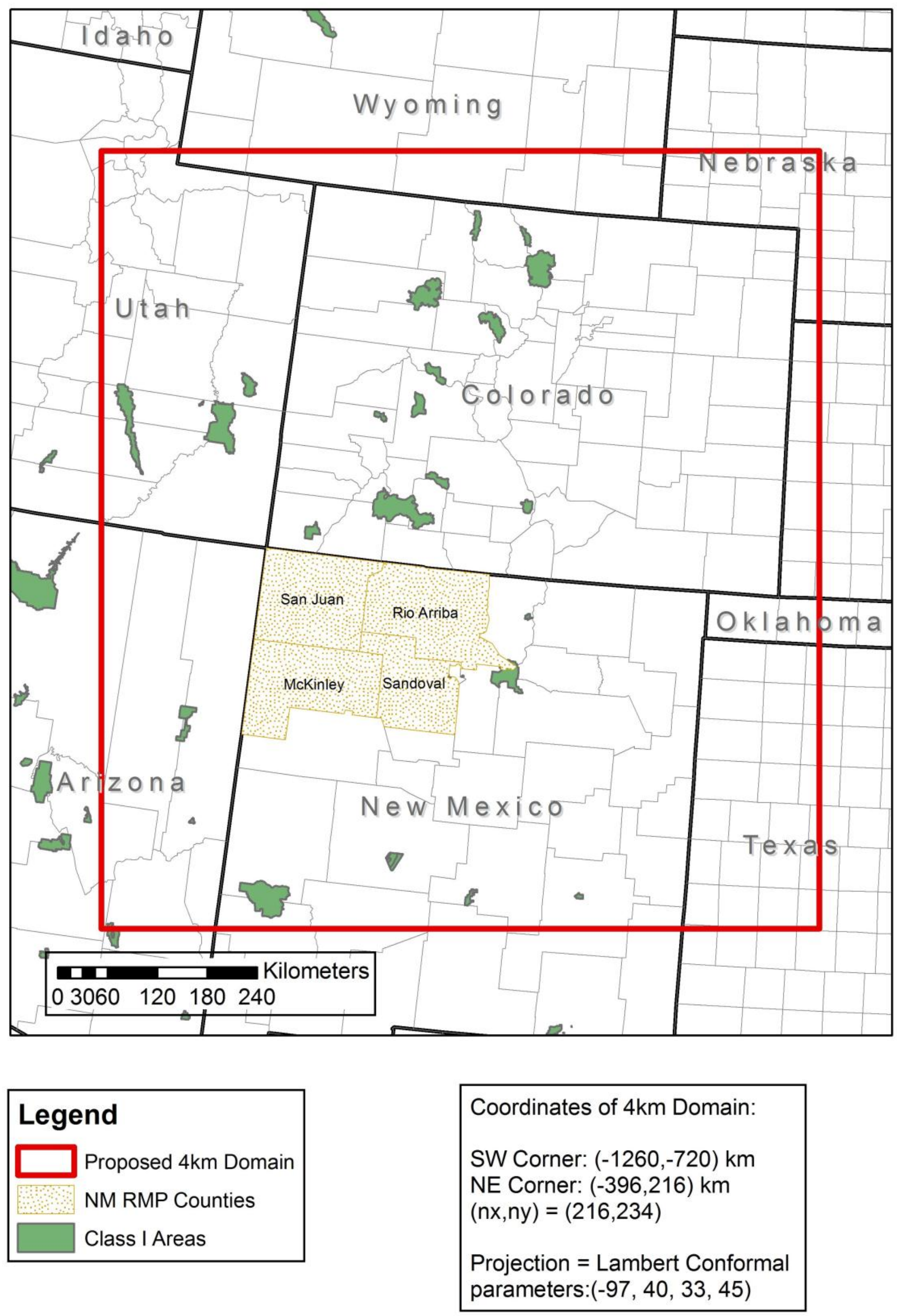

Figure 2-1. 4 km modeling domain used in the Colorado Air Resource Management Modeling Study (CARMMS).

Table 2-2. 37 Vertical layer interface definition for WRF simulations (left most columns), and approach for reducing to 25 vertical layers for CAMx/CMAQ by collapsing multiple WRF layers (right columns).

WRF Meteorological Model					CAMx/CMAQ Air Quality Model		
WRF Layer	Sigma	Pressure (mb)	Height (m)	Thickness (m)	CAMx Layer	Height (m)	Thickness (m)
37	0.0000	50.00	19260	2055	25	19260.0	3904.9
36	0.0270	75.65	17205	1850			
35	0.0600	107.00	15355	1725	24	15355.1	3425.4
34	0.1000	145.00	13630	1701			
33	0.1500	192.50	11930	1389	23	11929.7	2569.6
32	0.2000	240.00	10541	1181			
31	0.2500	287.50	9360	1032	22	9360.1	1952.2
30	0.3000	335.00	8328	920			
29	0.3500	382.50	7408	832	21	7407.9	1591.8
28	0.4000	430.00	6576	760			
27	0.4500	477.50	5816	701	20	5816.1	1352.9
26	0.5000	525.00	5115	652			
25	0.5500	572.50	4463	609	19	4463.3	609.2
24	0.6000	620.00	3854	461	18	3854.1	460.7
23	0.6400	658.00	3393	440	17	3393.4	439.6
22	0.6800	696.00	2954	421	16	2953.7	420.6
21	0.7200	734.00	2533	403	15	2533.1	403.3
20	0.7600	772.00	2130	388	14	2129.7	387.6
19	0.8000	810.00	1742	373	13	1742.2	373.1
18	0.8400	848.00	1369	271	12	1369.1	271.1
17	0.8700	876.50	1098	177	11	1098.0	176.8
16	0.8900	895.50	921	174	10	921.2	173.8
15	0.9100	914.50	747	171	9	747.5	170.9
14	0.9300	933.50	577	84	8	576.6	168.1
13	0.9400	943.00	492	84			
12	0.9500	952.50	409	83	7	408.6	83.0
11	0.9600	962.00	326	82	6	325.6	82.4
10	0.9700	971.50	243	82	5	243.2	81.7
9	0.9800	981.00	162	41	4	161.5	64.9
8	0.9850	985.75	121	24			
7	0.9880	988.60	97	24	3	96.6	40.4
6	0.9910	991.45	72	16			
5	0.9930	993.35	56	16	2	56.2	32.2
4	0.9950	995.25	40	16			
3	0.9970	997.15	24	12	1	24.1	24.1
2	0.9985	998.58	12	12			
1	1.0000	1000	0			0	

2.4 Meteorological Modeling Approach

The CARMMS meteorological inputs for the CAMx modeling are based on the WRF modeling performed as part of the Western Regional Air Partnership West-wide Jump Start Air Quality Modeling Study (WestJumpAQMS). The WRF computational domains were defined to be slightly larger than the CAMx and SMOKE modeling domains to eliminate the occurrence of boundary artifacts in the CAMx meteorological inputs. Such boundary artifacts can occur when the boundary conditions (BCs) for the meteorological variables come into dynamic balance with WRF's atmospheric equations and numerical methods.

The WRF model contains many different physics options, and achieving the best model performance for any particular year and region is accomplished by performing model sensitivity tests using different options. As part of the post-2008 Denver ozone SIP modeling, Alpine Geophysics, LLC and ENVIRON conducted numerous WRF meteorological sensitivity simulations to determine the best performing configuration for simulating meteorology in the Inter-Mountain West region (Morris et al., 2011). The final WRF configuration was used for the new 2008 Denver ozone modeling as well as for the WestJumpAQMS[10] who's WRF modeling results are used in CARMMS.

2.4.1 2008 WRF Modeling Methodology

The WestJumpAQMS 2008 WRF modeling methodology is described below. More details are provided in the WestJumpAQMS WRF Application/Evaluation report (ENVIRON and Alpine, 2012).

<u>Horizontal Domain Definition</u>: The computational domain on which WRF was applied for WestJumpAQMS included a 36 km CONUS, 12 km WESTUS and 4 km Inter-Mountain West Domain (IMWD). The 4 km domain includes the 4 km CARMMS domain shown in Figure 2-1. The grid projection is Lambert Conformal with a pole of projection of 40 degrees North, -97 degrees East and standard parallels of 33 and 45 degrees, the so-called RPO projection. The datum (size and shape of earth) is a perfect sphere with radius 6370.0 km.

<u>Vertical Domain Definition</u>: The WRF modeling was based on 37 vertical layers with an approximately 12 meter deep surface layer. The vertical domain is presented in both sigma and height coordinates in Table 2-2.

<u>Topographic Inputs</u>: Topographic information for WRF were developed using the standard WRF terrain databases. The 36 km domain is based on the 10 minute (18 km) global data. The 12 km domain is based on the 2 minute (~4 km) data. The 4 km domain is based on 30 second (~900 m) data

<u>Vegetation Type and Land Use Inputs</u>: Vegetation type and land use information were developed using the most recently released WRF databases provided with the WRF distribution. Standard WRF surface characteristics corresponding to each land use category were employed.

<u>Atmospheric Data Inputs</u>: The first guess fields were taken from the 12 km North American Model (NAM) database.

[10] http://www.wrapair2.org/pdf/WestJumpAQMS_2008_Annual_WRF_Final_Report_February29_2012.pdf

Diffusion Options: Horizontal Smagorinsky first-order closure (km_opt = 4) with sixth-order numerical diffusion and suppressed up-gradient diffusion (diff_6th_opt = 2) were used.

Lateral Boundary Conditions: Lateral boundary conditions were specified from the initialization dataset (12 km NAM) on the 36 km domain with continuous updates nested from the 36 km domain to the 12 km domain and continuous updates nested from the 12 km domain to the 4 km domain, using one-way nesting (feedback = 0).

Top and Bottom Boundary Conditions: The top boundary condition was selected as an implicit Rayleigh dampening for the vertical velocity. Consistent with the model application for non-idealized cases, the bottom boundary condition were selected as physical, not free-slip.

Water Temperature Inputs: The water temperature data were taken from the National Centers for Environmental Prediction (NCEP) Real Time Global (RTG) global one-twelfth degree analysis[11].

FDDA Data Assimilation: The WRF model was run with a combination of analysis and observation nudging (i.e., Four Dimensional Data assimilation [FDDA]). Analysis nudging was used on the 36 km and 12 km domain using the 12 km NAM dataset. For winds and temperature, analysis nudging coefficients of $5x10^{-4}$ and $3.0x10^{-4}$ were used on the 36 km and 12 km domains, respectively. For mixing ratio, an analysis nudging coefficient of $1.0x10^{-5}$ was used for both the 36 km and 12 km domains. The nudging uses both surface and aloft nudging with nudging for temperature and mixing ratio not performed in the lower atmosphere (i.e., within the boundary layer and at the surface). Observation nudging was performed on the 4 km grid domain using the Meteorological Assimilation Data Ingest System (MADIS)[12] observation archive. The MADIS archive includes the National Climatic Data Center (NCDC)[13] observations and the National Data Buoy Center (NDBC) Coastal-Marine Automated Network C-MAN[14] stations. The observational nudging coefficients for winds, temperatures and mixing ratios were $1.0x10^{-4}$, $1.0x10^{-4}$, and $1.0x10^{-5}$, respectively and the radius of influence was set to 50 km.

Physics Options: The WRF model contains many different physics options. The physics options chosen for the WestJumpAQMS application are presented in Table 2-3.

Application Methodology: The WRF model was executed in 5½ day blocks initialized at 12Z every 5 days. Model results were output every 60 minutes. The first twelve (12) hours of each 5 ½ day block is used for model spin-up and not used in the PGM model inputs or in the WRF model performance evaluation. WRF was configured to run in distributed memory parallel mode.

Table 2-3. Physics options used in the WestJumpAQMS WRF 2008 simulation modeling.

WRF Treatment	Option Selected	Notes
Microphysics	Thompson scheme	New with WRF 3.1.
Longwave Radiation	RRTMG	Rapid Radiative Transfer Model for GCMs includes

[11] Real-time, global, sea surface temperature (RTG-SST) analysis. http://polar.ncep.noaa.gov/sst/oper/Welcome.html
[12] Meteorological Assimilation Data Ingest System. http://madis.noaa.gov/
[13] National Climatic Data Center. http://lwf.ncdc.noaa.gov/oa/ncdc.html
[14] National Data Buoy Center. http://www.ndbc.noaa.gov/cman.php

WRF Treatment	Option Selected	Notes
		random cloud overlap and improved efficiency over RRTM.
Shortwave Radiation	RRTMG	Same as above, but for shortwave radiation.
Land Surface Model (LSM)	NOAH	Two-layer scheme with vegetation and sub-grid tiling.
Planetary Boundary Layer (PBL) scheme	YSU	Yonsie University (Korea) Asymmetric Convective Model with non-local upward mixing and local downward mixing.
Cumulus parameterization	Kain-Fritsch in the 36 km and 12 km domains. None in the 4 km domain.	4 km can explicitly simulate cumulus convection so parameterization not needed.
Analysis nudging	Nudging applied to winds, temperature and moisture in the 36 km and 12 km domains	Temperature and moisture nudged above PBL only.
Observation Nudging	Nudging applied to surface wind only in the 4 km domain	Surface temperature and moisture observation nudging can introduce instabilities.
Initialization Dataset	12 km North American Model (NAM)	Also used in analysis nudging

2.4.2 Meteorological Model Performance Evaluation

The WestJumpAQMS performed a comprehensive and detailed model performance evaluation of the 2008 WRF 36/12/4 km model simulation. The WestJumpAQMS WRF model performance evaluation is documented in a WRF Application/Evaluation report that is available on its website (ENVIRON and Alpine, 2012[15]). The WRF evaluation consisted of the following:

- Evaluation against surface meteorological observations of wind direction, wind speed, temperature and water vapor mixing ratio (humidity) with monthly performance statistics calculated using the METSTAT program:
    - Surface meteorological performance statistics were calculated across the 36 km CONUS, 12 km WESTUS and 4 km Inter-Mountain West domains, across each individual western state and at individual monitoring sites within each western state, including Colorado[16] that is the main focus of the CARMMS.
    - The surface meteorological model performance statistics were compared against model performance evaluation benchmarks in order to help interpret the WRF model performance and compare it with other studies that were used to develop the benchmarks. The 2008 WRF model performance was compared against both the simple (simple terrain and/or simple meteorological conditions) and complex (complex terrain and/or more complex meteorological conditions) model performance benchmarks.
    - The WRF 2008 precipitation estimates were compared with monthly analysis fields generated by the Climate Prediction Center (CPC) in a qualitative evaluation.

[15] http://www.wrapair2.org/pdf/WestJumpAQMS_2008_Annual_WRF_Final_Report_February29_2012.pdf
[16] http://www.wrapair2.org/pdf/westjump.wrf.site.co.2012-04-04.pdf

Appendix A summarizes some of the WestJumpAQMS WRF model performance evaluation products as they relate to WRF performance within the CARMMS 4 km modeling domain. The WestJumpAQMS 2008 WRF model performance within the CARMMS region is as good or better than meteorological model performance seen in past photochemical modeling studies of the region (e.g., WRAP regional haze modeling and Denver 2008 ozone State Implementation Plan modeling). Thus, the WestJumpAQMS 2008 WRF meteorological fields were judged to be appropriate for use in the CARMMS.

2.5 2008 BASE CASE EMISSIONS

The 2008 Base Case emissions were developed by the WestJumpAQMS. The primary source for the 2008 base case emissions is Version 2.0 of the National Emissions Inventory (NEIv2.0[17]). For most source categories, the SMOKE emissions modeling system was used to process the emissions into the hourly gridded speciated emissions needed as input for CAMx. The comprehensive and detailed documentation for the WestJumpAQMS 2008 Base Case emissions inventory is available on the WestJumpAQMS website[18] and includes a final report (ENVIRON, Alpine and UNC, 2013) and 16 Emissions Technical Memorandums that provide details on the 2008 emissions for each source category as well as for the parameters used in the emissions modeling.

2.5.1 Source of 2008 Base Case Emissions

Table 2-4 summarizes the emission models and sources of 2008 Base Case emissions that are based primarily on the 2008 NEIv2.0 with the following enhancements:

- Major (≥25 MW) Electrical Generating Units (EGUs) point source SO_2 and NO_X emissions used Continuous Emissions Monitor (CEM) measurement data that are available online from the EPA Clean Air Markets Division (CAMD[19]). These data are hour-specific for SO_2, NO_x and heat input. The temporal variability of other pollutant emissions (e.g., PM) for the CEM sources were estimated using the hourly CEM heat input data to allocate the annual emissions from the NEIv2.0 to each hour of the year. Emissions, locations and stack parameters for point sources without CEM devices were based on the 2008 NEIv2.0.
- The WRAP-IPAMS Phase III 2006 oil and gas emission inventories were projected to 2008 for all Phase III basins that were available at the time of the WestJumpAQMS 2008 emissions development. In addition, under WestJumpAQMS new oil and gas emissions inventory was developed for the Permian Basin in southeastern New Mexico/northwestern Texas.
- On-road mobile source emissions were based on the MOVES2010a[20] model with county-specific weekday and weekend day VMT and monthly meteorology for the 2008 base case modeling year.
- The WRAP windblown dust (WBD) model [21] was used to generate WBD emissions using day-specific hourly meteorology from the 2008 WRF simulation.

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[17] http://www.epa.gov/ttnchie1/net/2008inventory.html
[18] http://www.wrapair2.org/WestJumpAQMS.aspx
[19] http://www.epa.gov/airmarkets/
[20] http://www.epa.gov/otaq/models/moves/index.htm

- Sea salt and lightning emissions were generated using the 2008 WRF model hourly gridded output.
- Emissions from fires (wildfires, prescribed burns and agricultural burning) are based on the 2008 fire emissions inventory developed in the Joint Fire Sciences Program (JFSP) Deterministic and Empirical Assessment of Smoke's Contribution to Ozone (DEASCO3[22]) study.
- Biogenic emissions were generated using an enhanced version of the Model of Emissions of Gases and Aerosols in Nature (MEGAN[23]) that was updated by WRAP to better represent biogenic emissions for the western states.
- Mexico emissions were based on the 2008 projections from the 1999 Mexico national emissions inventory.
- The Environment Canada 2006 emissions inventory based on the National Pollutant Release Inventory (NPRI) was used for Canada.
- New spatial surrogates for the emissions were developed using the latest 2010 Census and other data that are now available and includes population and housing statistics for 2010. Details on the new spatial surrogates used for allocating county-level emissions to the 4 km grid cells can be found in the WestJumpAQMS Emissions Technical Memorandum Number 13[24].

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[21] http://www.wrapair.org/forums/dejf/fderosion.html
[22] https://www.firescience.gov/projects/11-1-6-6/proposal/11-1-6-6_11-1-6_attachment_1_primary.pdf
[23] http://acd.ucar.edu/~guenther/MEGAN/MEGAN.htm
[24] http://www.wrapair2.org/pdf/Memo13_Parameters_Sep30_2013.pdf

Table 2-4. Summary of sources of emissions and emission models used to generate 2008 base case emissions for use in CARMMS.

Emissions Component	Configuration	Details
Model Code	SMOKE Version 3.1	http://www.smoke-model.org/index.cfm
Oil and Gas Emissions	Update WRAP Phase III 2006 to 2008	Seven WRAP Phase III Basins in CO, NM, UT and WY plus add 2008 Permian Basin O&G Emissions
Area Source Emissions	2008 NEI Version 2.0	Western state updates, then SMOKE processing of http://www.epa.gov/ttn/chief/net/2008inventory.html
On-Road Mobile Sources	MOVES2010a	County specific emissions run for monthly weekday and weekend days. California based on EMFAC2011.
Point Sources	2008 CEM and Non-CEM Sources	Use 2008 day-specific hourly measured CEM for SO_2 and NO_X emissions for CEM sources, 2008 NEIv2.0 for other pollutants and non-CEM sources
Off-Road Mobile Sources	2008 NEIv2.0	Based on EPA NONROAD model http://www.epa.gov/oms/nonrdmdl.htm
Wind Blown Dust Emissions	WRAP Wind Blown Dust (WBD)	WRAP WBD Model with 2008 WRF meteorology adjusted to be consistent with 2002 WBD modeling
Ammonia Emissions	NEIv2.0	Based on CMU Ammonia Model. Review and update spatial allocation if appropriate.
Biogenic Sources	MEGAN	Enhanced version of MEGAN Version 2.1 from WRAP Biogenics study http://www.wrapair2.org/pdf/WGA_BiogEmisInv_FinalReport_March20_2012.pdf
Fires	2008 DEASCO3	2008 DEASCO3 fire inventory used. http://www.wrapair2.org/pdf/JSFP_DEASCO3_TechnicalProposal_November19_2010.pdf
Temporal Adjustments	Seasonal, day, hour	Based on latest collected information
Chemical Speciation	CB05 Chemical Speciation	CB6 considered but sensitivity modeling indicated in exacerbates an ozone overestimation issue.
Gridding	Spatial Surrogates based on landuse	Develop new spatial surrogates using 2010 census data and other data
Quality Assurance	SMOKE QA Tools; PAVE, VERDI plots; Summary reports	Follow WRAP emissions QA/QC plan.

2.5.2 On-Road Mobile Sources

The MOtor Vehicle Emissions Simulator (MOVES[25]) is EPA's current tool to construct on-road mobile source emissions estimates for national, state, and county level inventories of criteria air pollutants, greenhouse gas emissions, and some mobile source air toxics from highway vehicles (EPA, 2012a). In addition, MOVES can make projections for energy consumption (total, petroleum-based, and fossil-based). EPA requires that all new regulatory modeling studies use the MOVES model for mobile source emissions and MOVES is also recommended for NEPA studies (EPA, 2012c).

The CARMMS/WestJumpAQMS 2008 on-road mobile source emission modeling was conducted using MOVES2010a. In April 2012, EPA released MOVES2010b after WestJumpAQMS completed its MOVES modeling. According to EPA's documentation, the primary difference between MOVES2010b and MOVES2010a is related to performance issues (e.g., computing run time) and EPA reports that the emission estimates produced by the two versions of MOVES are nearly identical[26]. EPA's technical guidance for State Implementation Plans (SIPs) and transportation conformity notes that studies that started with MOVES2010a do not have to switch to the new MOVES2010b (EPA, 2012b[27]). Given the near identical emissions, EPA's MOVES modeling guidance and the significant effort WestJumpAQMS has invested in its MOVES modeling to date, rerunning with MOVES2010b is not necessary.

MOVES was configured to estimates emissions directly (i.e., emissions inventory mode) at a county level basis by month using the monthly average diurnally varying 2008 WRF meteorological conditions. Note that MOVES can also be used to estimate emissions factors (i.e., emissions factor mode) and a SMOKE-MOVES processor can be used with the hourly gridded WRF meteorological data with a MOVES emissions factor lookup table. However, at the time of the WestJumpAQMS mobile source emissions modeling, SMOKE-MOVES was in its development stage and not fully operational. The resulting mobile source emissions estimates were converted to SMOKE-ready area source, hourly data sets suitable for processing by SMOKE/SMKINVEN. A modified version of SMKINVEN is used to process the hour-specific emissions estimates. For California on-road mobile source emissions, 2008 county-level emissions were based on the EMFAC2011 model that was downloaded from the EMFAC website[28].

The MOVES/EMFAC estimated county-level on-road mobile source emissions estimates were spatially allocated to the 36/12/4 km modeling domains using the SMOKE emissions model and recent mobile source spatial surrogates developed using the 2010 census and other data. This includes new spatial surrogate categories specific to new source categories in MOVES (e.g., heavy duty truck idling at rest stops). As MOVES2010a estimates hourly on-road mobile source emissions estimates by county by month for a representative weekend day and weekday, there is no need to temporally allocate the emissions using SMOKE. However, in order for SMOKE to properly utilize the hourly emissions estimates from MOVES, a modified version of SMOKE is required. The MOVES hourly gridded mobile source emissions were chemically speciated to the CB05 chemical mechanism using CB05 chemical speciation profiles based on the SPECIATE4.3

[25] http://www.epa.gov/otaq/models/moves/index.htm
[26] http://www.epa.gov/otaq/models/moves/documents/420f12014.pdf
[27] http://www.epa.gov/otaq/models/moves/documents/420b12028.pdf
[28] http://www.arb.ca.gov/jpub/webapp//EMFAC2011WebApp/emsSelectionPage_1.jsp

database. More details on the 2008 on-road mobile source emissions can be found in the WestJumpAQMS Technical Memorandum No. 3 (Wilkinson, Loomis and Morris, 2012[29]).

2.5.3 Area and Non-Road Mobile Sources

The 2008 NEIv2.0 area and non-road emissions were processed using the SMOKE emissions model with new 2010 census spatial surrogates and default temporal and CB05 speciation adjustments. Several source categories within the area and non-road category were removed from the NEIv2.0 so that they could be replaced or updated and separately processed, which allows a more thorough QA/QC analysis. The source categories that were extracted from the NEIv2.0 area and non-road sources for separate treatment or replacement were as follows:

- Oil and gas (O&G) exploration and production sources for locations covered by most of the WRAP Phase III O&G Basins and the Permian Basin were removed from the 2008 NEIv2. They were replaced by the WRAP Phase III 2006 emissions projected to 2008 (see Section 2.5.4). New 2008 O&G emissions were developed for the Permian Basin in southeastern New Mexico/northwestern Texas. The 2008 NEIv2.0 O&G emissions will be used for the remainder of the U.S. locations, which includes the Williston and Great Plains Basins (North Dakota and Montana) whose WRAP Phase III emissions were not available at the time of the 2008 emissions inventory development.
- Ammonia emissions due to livestock and fertilizer sources were removed from the NEIv2.0 and processed separately.
- Aircraft, locomotive and marine (alm) sources were processed separately as their own source group in the emissions modeling. The marine sources do not include large ocean going (Class 3) vessels (Commercial Marine Vessels, CMV) that will be processed under the off-shore shipping category.
- Fire emissions were removed from the NEIv2.0 and were replaced by 2008 fire emissions developed as part of the DEASCO3 study.
- Fugitive dust emissions were removed from the NEIv2.0 for separate processing.

Below we summarize the processing area and non-road emissions used from the 2008 NEIv2 in the CARMMS 2008 base case, more details can be found in WestJumpAQMS Technical Memorandum No.2 Area and Non-Road Emissions (Loomis, Morris and Adelman, 2013[30]).

2.5.3.1 Area Sources

The NEI Area (or Non-Point) data category contains emission estimates for sources which individually are too small in magnitude or too numerous to inventory as individual point sources, and which can often be estimated more accurately as a single aggregate source for a County or Tribal area. Area source (non-point) emissions are emissions sources that are summed over a geographic region, rather than specifically located. Examples of area sources include small industrial, residential, consumer product, and agricultural emissions. For emissions modeling purposes, these types of emissions are defined by state and county (or tribal) identifiers, and SCC codes. After extracting the area source categories from the NEIv2.0

[29] http://www.wrapair2.org/pdf/Memo_3_MOVES_On-Road_June25_2012_final.pdf
[30] http://www.wrapair2.org/pdf/Memo_2_Area_Jan22_2013%20review%20draft.pdf

as indicated above, the remaining area sources in the NEIv2.0 were processed by SMOKE as their own source category.

2.5.3.2 Non-Road Sources

The NEI Non-Road data categories contain mobile sources which are estimated for version 2.0 of the 2008 NEI using the EPA NONROAD[31] model, run within the National Mobile Inventory Model (NMIM[32]). The non-road emissions have been compiled as both annual total emissions, and average day emissions by month. In order to take the best advantage of the monthly and seasonal variability of the non-road emissions sources, we used the monthly options for SMOKE modeling inputs.

Note that emissions data for aircraft, locomotives, and commercial marine vessels are not included in the NEI non-road data category starting with the 2008 NEI. These three non-road mobile source categories were handled as special cases, with separate input processing streams. Aircraft engine emissions occurring during Landing and Takeoff Operations (LTO) and the Ground Support Equipment (GSE) and Auxiliary Power Units (APU) associated with the aircraft are now included in the point data category at individual airports in the 2008 NEI. Emissions from locomotives that occur at rail yards are also included in the point data category. In-flight aircraft emissions, locomotive emissions outside of the rail yards, and commercial marine vessel emissions (both underway and port emissions) are included in the Non-Point data category.

2.5.4 2008 Oil and Gas Emissions

For Basins covered by the WRAP-IPAMS Phase III 2006 oil and gas (O&G) emissions available at the time of the 2008 base case emissions development, the WRAP Phase III O&G 2006 emissions were projected to 2008. WestJumpAQMS also developed new 2008 O&G emissions for the Permian Basin in southeastern New Mexico/northwestern Texas. For all other Basins in the U.S. (including Williston and Great Plains Basins whose WRAP Phase III emissions were not available at the time of the 2008 base case development) the 2008 O&G emissions from the NEIv2.0 were used and processed as area and point sources.

2.5.4.1 2008 Phase III O&G Emissions Update

The WRAP Phase III 2006 baseline O&G inventories were projected to 2008 for the following eight WRAP Phase III Basins:

- Denver-Julesburg Basin (CO)
- Piceance Basin (CO)
- Uinta Basin (UT)
- North San Juan Basin (CO)
- South San Juan Basin (NM)
- Wind River Basin (WY)
- Powder River Basin (WY)
- Greater Green River Basin (WY)

[31] http://www.epa.gov/otaq/nonrdmdl.htm
[32] http://www.epa.gov/otaq/nmim.htm

The 2008 O&G emission update for the WRAP Phase III and Permian Basins used 2008 O&G production statistics from the Enerdeq database published by IHS Global, also referred to as the "PI Dwight's" database. This database contains production statistics that are of significantly higher quality than the primary data in individual state O&G Commission databases.

Processing of the IHS data for the 2008 projections followed the same methodology as used in the WRAP Phase III study[33]. Summaries of production statistics were extracted from the IHS database, including well count by well type and location, spud count, production of gas by well type and well location, production of liquid petroleum (oil or condensate) by well type and well location, and production of water by well type and well location. All data were summarized at the county and basin level, for tribal and non-tribal land separately as applicable to each basin. No new survey work was conducted for the 2008 O&G emissions update so the analysis did not include any updates of company-specific production statistics as was done in the development of the Phase III 2006 O&G emission inventories. The resulting production statistics data were summarized at the county, tribal and basin levels for all basins including the Permian Basin.

The 2008 production statistics from the IHS database were used to project the Phase III baseline 2006 O&G inventories. The projections will be developed as scaling factors that represented the ratio of the value of a specific activity parameter in 2008 to the value in 2006. The scaling factors were developed at the county and tribal levels for all basins. Scaling factors were then matched to all source categories considered as part of the Phase III inventories, using the same cross-referencing analysis conducted as part of the midterm (2012) projections in the Phase III study. The 2008 to 2006 scaling factors were used to adjust the activity data for the oil and gas emissions.

Where specific scaling factors are estimated to be less than one (1), indicating a reduction in an activity parameter from 2006 to 2008, all emissions factors and activity data will be assumed to be identical in 2008 as in 2006 and the 2006 emissions will be reduced and no emission controls assessment is needed (i.e., when activity is reduced between 2006 and 2008 we are assuming that the same equipment is being used in the field, it is just producing less). In this case, the 2008 emissions will be developed assuming the direct application of the scaling factor with no additional controls.

Where scaling factors are estimated to be greater than one (1), it is assumed that some growth in activity has occurred in the 2006-2008 time period and that new equipment may have been deployed in the field. A controls analysis was conducted specific to each basin and utilizing the control measures identified as part of the WRAP Phase III midterm O&G projections work. The controls analysis only considered broad control factors, rather than detailed analyses as conducted in the Phase III midterm projections. Where no significant impact of controls from federal or state regulations are anticipated in the 2006-2008 time period, no control factors for the specific source category will be assumed.

For Colorado Basins, the permitted O&G 2008 emissions were based on the CDPHE 2008 APEN database rather than projected from the WRAP Phase III 2006 O&G emissions, whose permitted O&G emissions were based on the CDPHE 2006 APEN database. In addition, the Colorado Department of Health and Development (CDPHE) has determined that not all condensate Flash

[33] http://www.wrapair2.org/PhaseIII.aspx

VOC emissions that were assumed to be controlled 95% by flares make it to the flare and are instead vented to the atmosphere. Thus, CDPHE has introduced the concept of a Capture Efficiency (CE) for condensate flare control that assumes only 75% of the condensate Flash VOC emissions are actually controlled by the flare and the other 25% is released directly to the atmosphere. The CDPHE 75% CE assumption was adopted in the CARMMS/WestJumpAQMS 2008 base case O&G emissions in Colorado. The WRAP Phase III 2006 unpermitted condensate tank O&G emissions are either projected to 2008 (D-J Basin) or the 2008 APEN condensate tank emissions are reduced (Piceance Basin) in order for the total 2008 condensate production in the inventory to match the 2008 IHS database production statistics.

Details on the development of the 2008 O&G emissions for the Colorado Basins, the Uinta and South San Juan Basins and the Wyoming Basins can be found in, respectively, Bar-Ilan and Morris (2012a[34]), Bar-Ilan and Morris (2012b[35]) and Bar-Ilan and Morris (2012c[36]).

2.5.4.2 2008 Emission Inventory for the Permian Basin

A study prepared by Applied EnviroSolutions, Inc. (AES) on 2007 O&G emissions in the New Mexico portion of the Permian Basin along with 2008 O&G emissions from the Texas Commission on Environmental Quality (TCEQ) was used to develop a comprehensive O&G emissions inventory of the Permian Basin. Since the Permian Basin lies outside of the CARMMS modeling domain, details on the development of O&G emissions for the Permian Basin can be found in WestJumpAQMS Emissions Technical Memorandum Number 4d (Bar-Ilan and Morris, 2013[37]).

2.5.4.3 2008 O&G Emissions for the Remainder of the U.S.

The WRAP Phase III Basins and Permian Basin O&G emissions described above covers most of an area including northwestern TX, NM, CO, UT and WY. For areas within these states not covered by the WRAP Phase III and Permian Basins, and O&G emissions outside of this region, the O&G emissions from the 2008 NEIv2.0 were used. Details on the O&G emissions used in the 2008 base case not covered by the WRAP Phase III Basins can be found in WestJumpAQMS Technical Memorandum No. 4e (Loomis, Adelman, Morris and Bar-Ilan, 2013[38]).

2.5.5 Fire Emissions

2008 emissions from wild fires, prescribed burns and agricultural burning were based on the comprehensive 2008 fire emissions inventory developed as part of the DEASCO3[39] project sponsored by the Joint Fire Science Program (JFSP). The WestJumpAQMS emissions Technical Memorandum Number 5 (Morris, Tai, Loomis and Adelman, 2012[40]) discusses and compares available fire emissions for 2008. Details on the DEASCO3 fire emissions development

[34] http://www.wrapair2.org/pdf/Memo_4a_OG_Jun06_2012_Final.pdf
[35] http://www.wrapair2.org/pdf/Memo_4b_OG_June06_2012_Final.pdf
[36] http://www.wrapair2.org/pdf/Memo_4c_OG_Jan23_2013_RevisedFinal.pdf
[37] http://www.wrapair2.org/pdf/Memo_4d_OG_Apr24_2013_Final.pdf
[38] http://www.wrapair2.org/pdf/Final_Memo_4e_RemainderOG_Mar6_2013.pdf
[39] http://www.wrapair2.org/pdf/JSFP_DEASCO3_TechnicalProposal_November19_2010.pdf
[40] http://www.wrapair2.org/pdf/Memo_5_Fires_Apr27_2012_Final.pdf

methodology[41] and the methodology for fire plume rise and speciation[42] is available on the DEASCO3 website.

2.5.6 Ammonia Emissions

Ammonia emissions were based on the 2008 NEIv2.0 emissions inventory. A vast majority of the ammonia emissions in the 2008 NEIv2.0 were from livestock and fertilizer application that were based on the CMU ammonia model[43]. Updated spatial surrogates for locations of Concentrated Animal Feeding Operations (CAFOs) in Colorado developed as part of the NPS ROMANS study were used to spatially allocate the NEIv2.0 livestock ammonia emissions in Colorado, which greatly improves the ammonia emissions within the CARMMS domain. Details on the development of the ammonia emissions used in the CARMMS 2008 base case can be found in the WestJumpAQMS Technical Memorandum No. 8 (Loomis, Wilkinson, Adelman and Morris, 2013[44]).

2.5.7 Ocean Going Vessels

The 2008 off-shore shipping emissions inventory was based on the 2008 NEIv2.0. These emissions are developed and carried as point sources, rather than the area-level files generally used for off-road mobiles sources, including marine emissions sources. Details on the Off-Shore Shipping emissions are provided in a report "Documentation for the Commercial Marine Vessel Component of the National Emissions Inventory – Methodology" prepared by Eastern Research Group (ERG, 2010[45]) dated March 30, 2010. The WestJumpAQMS emissions Technical Memorandum Number 7 (Loomis, Morris and Adelman, 2012[46]) describes the off-shore shipping emissions and how they were processed for input into the photochemical grid model.

2.5.8 Biogenic Emissions

WRAP performed a Western Biogenic Emissions Update Study that enhanced the MEGAN biogenic emissions model to better simulate biogenic emissions in the western U.S. The CARMMS used the new enhanced version of MEGAN along with the 2008 WRF 36/12/4 km data to generate hourly gridded speciated biogenic emission inputs for 2008 and the CARMMS 4 km domain. Details on the WRAP Biogenic Emissions Update Study can be found in the study's final report (Sakulyanontvittaya, Yarwood and Guenther, 2012[47]) with a summary provided in the WestJumpAQMS emissions Technical Memorandum Number 9 on biogenic emissions (Sakulyanontvittaya et al., 2012[48]).

2.5.9 Spatial Allocation

New spatial allocation surrogates were developed at 4 km resolution for the CONUS domain using the latest 2010 CENSUS and other new data. The 4 km surrogate distributions were used directly for disaggregating the county-level emissions to the 4 km grid cells in the CARMMS modeling domain, as well as collapsed to 36 and 12 km resolution for spatial allocation to the

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[41] https://wraptools.org/pdf/ei_methodology_20130930.pdf
[42] https://wraptools.org/pdf/DEASCO3_Plume_Rise_Memo_20131210.pdf
[43] http://www.cmu.edu/ammonia/
[44] http://www.wrapair2.org/pdf/Memo8_AmmoniaSources_Feb28_2013review_draft.pdf
[45] http://www.epa.gov/ttn/chief/net/nei08_alm_popup.html
[46] http://www.wrapair2.org/pdf/OffshoreShippingEmissionsMemo_7WestJumpAQMS_Jan23_2012.pdf
[47] http://www.wrapair2.org/pdf/WGA_BiogEmisInv_FinalReport_March20_2012.pdf
[48] http://www.wrapair2.org/pdf/Memo_9_Biogenics_May9_2012_Final.pdf

36 km CONUS and 12 km WESTUS domains used in WestJumpAQMS modeling. Table 2-5 summarizes the spatial surrogates to be used for spatial allocation in the CARMMS/WestJumpAQMS SMOKE emissions modeling. More details are provided in the WestJumpAQMS emissions Technical Memorandum Number 13 on SMOKE modeling parameters (Adelman, Loomis and Morris, 2013[49]).

Table 2-5. Spatial surrogate distributions to be used in the SMOKE emissions modeling spatial allocations.

Shapefile	Description	Type	Year	Source
cty_pophu2k_revised	U.S. County Boundaries	Polygon	2005	U.S. Census Bureau
pophu_bg2010	Population/ Housing	Polygon	2010	U.S. Census Bureau
rd_ps_tiger2010	Roadways	Line	2010	U.S. Census Bureau
waterway_ntad2011	Waterways	Line	2010	U.S. Bureau of Transport Statistics
rail_tiger2010	Railways	Line	2010	U.S. Census Bureau
exits**	Highway Exits	Point	2010	ESRI
mjrrds**	Major Roads	Line	2010	ESRI
transterm**	Transportation Terminals	Point	2010	ESRI
fema_bsf_2002bnd	Building footprints	Polygon	2010	FEMA
heating_fuels_acs0510_c2010	Home heating fuels	Polygon	2010	U.S. Census Bureau

2.5.10 Temporal Allocation

Temporal profiles are available from the U.S. EPA for a wide range of emissions sources. While the majority of the temporal profiles available from the EPA represent nationally averaged emissions sources, state-specific monthly profiles exist for prescribed fires, wildfires, livestock, and some mobile sources. For most sources the emissions modeling temporal allocations were based on the U.S. EPA temporal profiles distributed with the 2008 NEIv2.0[50] (filename: amptpro_2008aa_us_can_revised_06oct2011_v0.txt). Several source categories use episode emissions that already have hourly emissions so will not use the temporal allocation profiles. These emissions categories include: large point sources with measured hourly CEM emissions; on-road mobile sources that use the MOVES monthly weekday/weekend day hourly emissions; biogenic emissions from MEGAN; and fire emissions from DEASCO3. The EPA default cross walk file between SCC codes and temporal allocations is available on the NEIv2.0 website[51].

2.5.11 Chemical Speciation

The U.S. EPA develops speciation profiles from information stored in the SPECIATE database[52]. The current SPECIATE database (version 4.3) is the official repository of volatile organic compound (VOC) and particulate matter (PM) emissions source profiles for different categories of emissions sources. SPECIATE contains 5,592 profiles of chemical mass fractions from source

[49] http://www.wrapair2.org/pdf/Memo13_Parameters_Feb28_2013review_draft.pdf
[50] http://www.epa.gov/ttnchie1/net/2008inventory.html
[51] ftp://ftp.epa.gov/EmisInventory/2008v2/doc/scc_eissector_xwalk_2008neiv2.xlsx
[52] http://www.epa.gov/ttnchie1/software/speciate/

testing conducted by EPA, state agencies, or published in the literature since the 1970's. Of the current profiles in SPECIATE, 3,570 are for PM sources, 1,775 are for VOC sources, and 247 are for other gases, such as mercury. The most recent update to the SPECIATE database occurred with the release of version 4.3 in September 2011. SPECIATE 4.3 include 405 new profiles obtained from a combination of recommendations for EPA Office of Transportation and Air Quality, EPA and state-sponsored studies of various industrial processes, and literature reviews conducted by the SPECIATE workgroup.

Part of the speciation process for VOCs includes converting inventory reactive organic gases (ROG) to total organic gases (TOG). This step is required because inventoried VOC excludes methane in the mass of total VOC while the speciation profiles include methane. Before the speciation profiles can be applied to the inventory, the inventory VOC must be scaled up to account for the missing methane mass. SCC-specific ROG-to-TOG conversion factors are included with the speciation profiles to prepare the inventories for speciation.

The CARMMS CAMx photochemical grid modeling is using the Carbon Bond version 05 (CB05) chemical mechanism (Yarwood et al., 2005[53]). The SMOKE emissions modeling will be performed using CB05 speciation profiles, based on the SPECIATE V4.3 database, and ROG-to-TOG conversion factors. The Speciation Tool is an interface to the SPECIATE database that develops CB05 VOC speciation profiles for use in the SMOKE emissions modeling. The exception to using the SPECIATE V4.3 VOC speciation profiles was for the WRAP Phase III Basins where Basin-specific CB05 VOC speciation profiles were used for O&G VOC emissions.

2.5.12 Emissions Quality Assurance and Quality Control

The emissions modeling quality assurance (QA) and quality control (QC) procedures developed as part of the WRAP Regional Modeling Center are being used in the CARMMS and WestJumpAQMS emissions modeling (Adelman, 2004). The 2008 base case emissions are processed by major source category in several different "streams" of emissions modeling. This is done in order to assist in the QA/QC of the emissions modeling as it is much easier to identify potential issues in the emissions fields when analyzing single source categories at a time. Each stream of emissions modeling generates a pre-merged CAMx-ready emissions model input with all pre-merged emissions inputs merged together to generate the final CAMx-ready two-dimensional gridded low-level (layer 1) and point source emission inputs. Table 2-6 lists an example of separate streams of emissions modeling by source category that can be used. Also shown in Table 2-6 are the source of the emissions, processing comments and the temporal allocation strategy whose options are as follows:

- Single day per year (aveday_yr)
- Single day per month (aveday_mon)
- Typical Monday, Weekday, Saturday, Sunday per year (mwdss_yr)
- Typical Monday, Weekday, Saturday, Sunday per month (mwdss_mon)
- Emissions estimated for each model simulation day (daily)
- Emissions estimated for each model simulation day with temporal profiles generated with average daily meteorology (daily met)

[53] http://www.camx.com/publ/pdfs/cb05_final_report_120805.aspx

- Emissions estimated for each model simulation day with temporal profiles generated with hourly meteorology (hourly met)

Table 2-6. Emissions processing categories and temporal allocation approach for 2008 Base Case emissions modeling.

No.	Emissions Processing Category (Abbr)	Inventory Source	Temporal	Processing Comments
1	Nonpoint/Area (nonpt)	NEI	mwdss_mon	Remove oil & gas, agricultural NH3, and dust,; includes commercial marine and rail
2	Livestock NH3 (lv)	NEI	mwdss_mon	Do not apply met-based temporal profiles; separate out for possible sensitivity later
3	Fertilizer NH3 (ft)	NEI	mwdss_mon	Group with lv as a full agricultural NH3 sector (ag)
4	Fugitive and Road Dust (fd)	NEI	mwdss_mon	Includes paved and unpaved road dust; apply transport factors but not met factors
5	Residential Wood Combustion (rwc)	NEI	mwdss_mon	Do not apply met-based temporal profiles; separate out for possible sensitivity later
6	Area Oil & Gas from P3 (ogp3)	WRAP P3	mwdss_mon	Basin specific speciation profiles and spatial surrogates (includes Permian Basin)
7	Area Oil and Gas from NEI (ognei)	NEI	MWDSS_mon	Use default speciation and allocations
8	Nonroad mobile (nr)	NEI	mwdss_mon	Includes NMIM commercial marine and rail
9	MOVES RPD (rpd)	MOVES	hourly met	
10	CEM Point (ptcem)	NEI08/CAMD	daily	Anomalies removed from 2008 CAMD data
11	Non-CEM Point (ptncem)	NEI08	mwdss_mon	Removed oil & gas sources from NEI and transferred to ptognei sector
12	Point Oil & Gas from P3 (ptogp3)	WRAP P3	mwdss_mon	WRAP Phase III inventory and Permian Basin
13	Point Oil & Gas from NEI (ptognei)	WRAP NEI	mwdss_mon	Remove NEI oil and gas emissions for counties in WRAP P3/Permian Basins
14	Point Fires (ptfire)	FINN or SMARTFIRE	daily	
15	Commercial Marine (ptseca)	NEI	aveday_mon	Latest version from Emissions Control Area (ECA) rule
16	Lightning NO_X (lnox)		hourly met	Gridded hourly NO emissions tied to WRF convective rainfall (optional)
17	Sea salt (ss)		hourly met	Surf zone and open ocean PM emissions (Optional)
18	Windblown Dust (wbd)	TBD	hourly met	WRAP WBD model one option
19	MEGAN Biogenic (bg)	MEGAN2.1	hourly met	Use new versions of MEGAN V2.10 updated by WRAP for the western U.S.
20	Mexico Area (mexar)	Mexico NEI	mwdss_mon	Mexico inventory projected from 1999 to 2008
21	Mexico Point (mexpt)	Mexico NEI	mwdss_mon	Mexico inventory projected from 1999 to 2013
22	Mexico Mobile (mexmb)	Mexico NEI	mwdss_mon	Mexico inventory projected from 1999 to 2013
23	Canada Area (canar)	Canada NPRI	mwdss_mon	Latest Environment Canada Inventory
24	Canada Point (canpt)	Canada NPRI	mwdss_mon	Latest Environment Canada Inventory
25	Canada Mobile (canmb)	Canada NPRI	mwdss_mon	Latest Environment Canada Inventory
26+	BLM Planning Areas	BLM	Mwdss_mon	Separate processing of O&G and mining emissions in each BLM Planning Area

Separate QA/QC is performed for each separate stream of emissions processing and in each step. SMOKE includes advanced quality assurance features that include error logs when emissions are dropped or added. The QA/QC procedures developed under the WRAP RMC will be used (Adelman, 2004) that includes visual displays that such as:

- Spatial plots of the hourly emissions for each major species (e.g., NOX, VOC, some speciated VOC, SO2, NH3, PM and CO);
- Vertical average emissions plots for major species and each of the grids;
- Diurnal plots of total emissions by major species and by state; and
- Summary tables of emissions for major species for each grid and by major source category.
- This QA information will be examined against the original point and area source data and summarized in an overall QA/QC assessment.

Scripts to perform the emissions merging of the appropriate biogenic, on-road, non-road, area, low-level, fire, and point emission files were written to generate the CAMx-ready two-dimensional day-specific hourly speciated gridded emission inputs. The point source and, as available elevated fire, emissions were processed into the day-specific hourly speciated emissions in the CAMx-ready point source format.

The resultant CAMx model-ready emissions were subjected to a final QA using spatial maps, vertical plots and diurnal plots to assure that: (1) the emissions were merged properly; (2) CAMx inputs contain the same total emissions; and (3) to provide additional QA/QC information.

2.6 2008 Base Case Modeling and Model Performance Evaluation

WestJumpAQMS performed a CAMx 2008 4 km Base Case simulation for the CARMMS 4 km modeling domain and conducted a model performance evaluation. The CARMMS model performance evaluation was documented in Section 4.5.3 in the WestJumpAQMS final report (ENVIRON, Alpine and UNC[54]). The CARMMS study intended to rely on the WestJumpAQMS CAMx model performance evaluation that focused on monthly and annual model performance statistics across the 4 km CARMMS domain for ozone, $PM_{2.5}$ and related species. However, when presenting the CARMMS 2008 Base Case modeling and model performance evaluation results to the IAQRT at a February 28, 2014 meeting, the IAQRT requested that more model performance information be provided. In particular, the IAQRT requested that ozone model performance statistics be calculated using a 60 ppb observed ozone cut-off concentration instead of 40 ppb as used by WestJumpAQMS, and that model performance statistics be provided down to an individual monitoring site. Thus, CARMMS calculated additional ozone model performance statistics using the 60 ppb ozone cut-off and packaged up all of the WestJumpAQMS model performance products for the 4 km CARMMS domain and 2008 Base Case simulation. The result was a 72 Mb zipped file of model performance products that had over 4,500 model performance statistics and displays that summarized model performance down to the individual monitoring site for each month and for each day of 2008 across the 4 km CARMMS domain. The zipped file of model performance products was provided to the IAQRT.

[54] http://www.wrapair2.org/pdf/WestJumpAQMS_FinRpt_Finalv2.pdf

Appendix B summarizes the CARMMS CAMx 2008 Base Case simulation and model performance evaluation across the 4 km CARMMS domain. The CARMMS CAMx Base Case simulation achieved EPA's ozone model performance goals, except in the winter months using a 60 ppb ozone cut-off. The CARMMS CAMx Base Case simulation also mostly achieved the PM Performance Criteria.

3.0 FUTURE YEAR EMISSIONS

The meteorological base year for the CARMMS modeling is 2008. The development of the 2008 Base Case modeling database and emissions scenario was described in Chapter 2. In this section we described the development of the future year emissions scenario. The future year emissions scenario modeled is 2021. Projecting future year oil and gas (O&G) emissions has many uncertainties as it depends on economic conditions (e.g., price of natural gas), identification of new O&G plays, availability of exploration and development equipment and regulatory requirements. For CARMMS future year, O&G emissions were developed for a range of potential outcomes that would hopefully bound the actual future year O&G development in the region. CARMMS is developing three levels of 2021 future year O&G development within the BLM Colorado Planning Areas:

- High Development Scenario;
- Low Development Scenario; and
- Medium Development Scenario.

There are four general types of future year emissions addressed in CARMMS:

1. BLM-authorized (Federal lands) and other (non-Federal lands) oil and gas and mining emissions within the Colorado BLM planning areas (as well as the BLM Farmington District Office in northern New Mexico);

2. Oil and gas and other development areas outside of Colorado/northern New Mexico BLM Planning Areas that are the focus of CARMMS;

3. Remainder future year anthropogenic emissions; and

4. Emissions related to the 2008 base year that remain unchanged in the future year scenarios.

3.1 Western Colorado BLM Planning Area Oil and Gas Emissions

To address emissions from future BLM-authorized (Federal lands) and non-BLM-authorized (non-Federal lands) oil and gas development in the western Colorado planning areas CARMMS has developed several emission calculators. Existing emissions calculators have been improved under CARMMS and representative calculators for “typical” crude oil, conventional gas (with condensate), coal bed natural gas (CBNG), and shale gas within the region have been developed. New information has been incorporated for drilling times; engine configurations; condensate and produced water production; well pad versus offsite gas treatment and storage; well-head, infield, and pipeline compression; and gas/oil production. The ability to readily modify input assumptions, such as production parameters, emission control assumptions, and wellhead equipment configurations, has also been incorporated into the calculator.

The refined emission calculators were used to develop the 2021 future-year O&G emissions inventories for the eight western Colorado BLM planning areas. The O&G emission calculators were also updated using information provided by the BLM New Mexico Farmington Field Office (FFO) petroleum engineers to estimate future year O&G emissions for the Mancos Shale Development area in northern New Mexico.

The following sections summarize the emission calculators used to estimate the O&G and mining emissions for western Colorado and northern New Mexico. Details on the emission calculators are provide in two Technical Memorandums (Grant, Zapert and Morris, 2013a,b) that are included as Appendices C and D.

3.1.1 Overview of Calculators

Emission calculators have been developed for each of the following well types.

- Conventional gas
- Conventional oil
- Shale gas
- Coalbed natural gas (CBNG)

For each well type, a separate self-contained emission calculator spreadsheet contains all of the inputs and calculations need to generate well site emissions.

Additionally, a calculator has been developed to estimate midstream emissions for each area. The midstream emission calculator draws upon Colorado Department of Public Health (CDPHE) Air Pollutant Emission Notice (APEN) emissions for base year emission estimates. Future year midstream emission projections are dependent on the change in oil and gas production in a given planning area which can be updated based on linkages to the by well type emission calculators.

3.1.2 Pollutants

The emission calculators include estimates of emissions of criteria air pollutants (CAPs), greenhouse gases (GHGs), and hazardous air pollutants (HAPs) as follows:

- Criteria Pollutants
  - Carbon monoxide (CO)
  - Nitrogen oxides (NOX)
  - Particulate matter less than or equal to 10 microns in diameter (PM10)
  - Particulate matter less than or equal to 2.5 microns in diameter (PM2.5)
  - Sulfur dioxide (SO2)
  - Volatile Organic Compounds (VOCs)
- Greenhouse Gases[55]
  - Carbon dioxide (CO_2)
  - Methane (CH_4)
  - Nitrous oxide (N_2O)
- Hazardous Air Pollutants (HAPs)[56]

[55] Note that the CARMMS PGM modeling does not use Greenhouse Gas (GHG) emissions, but the emission calculators provide GHG emission estimates so they can be reported in the RMPs.
[56] Note that the CARMMS PGM modeling does not use HAPs emissions, but the emission calculators provide HAPs emission estimates so they can be reported in the RMPs.

While lead (Pb) is a criteria pollutant, emissions of lead in the BLM western Colorado planning areas are expected to be extremely low and are therefore not included in this analysis.

HAP emissions were estimated for each emissions source. For oil and gas emissions sources, HAP emissions from venting and combustion source categories were estimated for formaldehyde, n-hexane, benzene, toluene, ethylbenzene, and xylenes (BTEX).

Anthropogenic greenhouse gas emission inventories typically include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases. Fluorinated gases are not expected to be emitted in appreciable quantities by any category considered in this emission inventory and were therefore not included in this analysis.

3.1.3 Temporal

The calculators estimate annual emissions associated with oil and gas exploration. Baseline emissions are estimated for 2011 with annual emission forecasts made for every year out to 10 years (2021).

3.1.4 Calculator Inputs

The emission calculator for each well type allows for specification of the following inputs.

- Base year oil and gas activity (gas production, oil production, spud counts, active well counts)
- Well decline estimates
- Level of control by source category
- Gas composition
- Equipment configurations (e.g. drill rigs, fracing rigs)
- Gas venting activity (e.g. completions, blowdowns)

The midstream emission calculator includes estimates of base year 2011 gas plant and compressor station emissions are taken from CDPHE APEN data. Base year midstream emissions are projected to future years based upon the gas production in each planning area.

3.1.5 Emission Calculations

Emission calculations for all emission-generating activities were developed based on typical emission inventory methodology. Methods used to estimate emissions from each source category are explained in detail in Appendix C (Grant, Zapert and Morris, 2013a). For each source category, emissions for the 2011 baseline were estimated. Emissions were then forecasted to future years, accounting for activity growth and for applicable sources emissions controls.

The methodologies described here are used consistently in all four calculators by well type; however the input data of each calculator was selected to best reflect the operational characteristics of each well type (oil, gas, CBNG, and shale gas) and thus obtained from literature sources including the following Air Quality Technical Support Documents (AQTSD) from Colorado field office planning areas and BLM emission calculators:

- White River AQTSD (URS, 2012a)
- Colorado River Valley AQTSD (URS, 2012b)
- Grand Junction AQTSD (BLM, 2012b)
- Uncompahgre AQTSD (in preparation)
- BLM Crude Oil Well Gas Emission Calculator
- BLM Coalbed Natural Gas Well Emission Calculator

Emissions are generated in three main phases of oil and gas systems:

- Emissions from Well Construction and Development
- Emissions from the Production Phase (occurring at-or-nearby the well pad)
- Emissions from Midstream Sources (Central Gas Compression and Processing)

The methodologies implemented to estimate base year and future year emissions from oil and gas sources are explained in Appendix C (Grant, Zapert and Morris, 2013a) and covered the following source categories:

- Well pad construction and development:
    - Well pad, access road and pipeline construction equipment;
    - Well pad, access road and pipeline construction traffic;
    - Drilling and completion equipment;
    - Fracing equipment;
    - Refracing equipment;
    - Drilling and well completion traffic;
    - Well pad, access road and pipeline construction wind erosion; and
    - Well completion venting.

- Production phase emissions:
    - Well workover equipment;
    - Production traffic;
    - Blowdown venting;
    - Well recompletion venting;
    - Pneumatic devices and fugitive components;
    - Water injection pumps;
    - Compressor station maintenance traffic exhaust and fugitive dust;
    - Condensate or oil tanks flashing and working and breathing losses;
    - Loading emissions from condensate and oil tanks;
    - Haul trucks traffic emissions;
    - Heaters; and
    - Dehydrators;

- Midstream sources:

- Natural gas processing facilities;
- Natural gas compressor stations; and
- Gas sweetening.

The oil and gas emission calculators are designed to estimate emissions from both BLM-authorized and non-BLM-authorized activities within the western Colorado BLM planning areas. Emissions were also estimated for coal and uranium mines on federal lands in the western Colorado BLM planning areas. However, unlike the oil and gas emissions, emissions from mines not on federal lands were not estimated and will need to be obtained from other sources for the photochemical modeling. The emissions for mines on federal lands were estimated for the baseline (2011) and future years and were based on the CDPHE APEN database and available EISs and EAs. Details on the mining emissions are given in Appendix D (Grant, Zapert and Morris, 2013b). Emissions were estimated for the following mines (BLM field office in parenthesis):

- Book Cliffs Area (Grand Junction).
- McClane (Grand Junction).
- Oak Mesa Area (Uncompahgre).
- King (Tres Rios).
- Foidel (Kremmling).
- Deserado (White River).
- Trapper (Little Snake).
- Colowyo (Little Snake).
- Sage Creek (Little Snake).
- West Elk (Uncompahgre).
- Elk Creek (Uncompahgre).

3.2 Oil and Gas Emissions outside of the BLM Western Colorado Planning Areas

The following three sections describe the procedures for estimating baseline and future year oil and gas emissions for areas within the CARMMS 4 km modeling domain but outside of the western Colorado BLM planning areas.

3.2.1 Colorado Royal Gorge Field Office

Baseline and future year oil and gas emissions for the BLM Royal Gorge Field Office[57] planning area in eastern Colorado were based on a recent study performed by URS Corporation for the BLM COSO. More information will be provided when that study is released.

3.2.2 South San Juan Basin, New Mexico

Emissions for oil and gas emissions for the New Mexico BLM Farmington District Office in the South San Juan Basin that includes San Juan, Rio Arriba, Sandoval and McKinley Counties were estimated based on oil and gas activity provided by the New Mexico BLM State and Farmington District Offices for the Mancos Shale Play and WRAP WestJumpAQMS 2008 oil and gas emissions. Figure 3-1 displays the oil and gas development areas in the Mancos Shale

[57] http://www.blm.gov/co/st/en/fo/rgfo.html

development area in northern New Mexico whose formation extends a little bit up into Colorado. The Mancos Shale Oil development is still in the exploratory phase with some encouraging results. The formation is split into an oil prone area in the south and a gas prone area to the north (Figure 3-1). The oil development is expected to occur at a rate of approximately 400 wells per year starting around 2015. The development of the gas prone area to the north (dry gas with little or no fluids) is dependent on the price of natural gas and is expected to be intensively developed starting approximately five years after the oil prone area.

70% of the new O&G emissions due to the Mancos Shale development are assumed to occur on Federal lands (i.e., BLM-authorized) and these emissions will be attributed to the New Mexico BLM Farmington District Office even though there are small amounts of emissions within the BLM Colorado Tres Rios Field Office Planning Area.

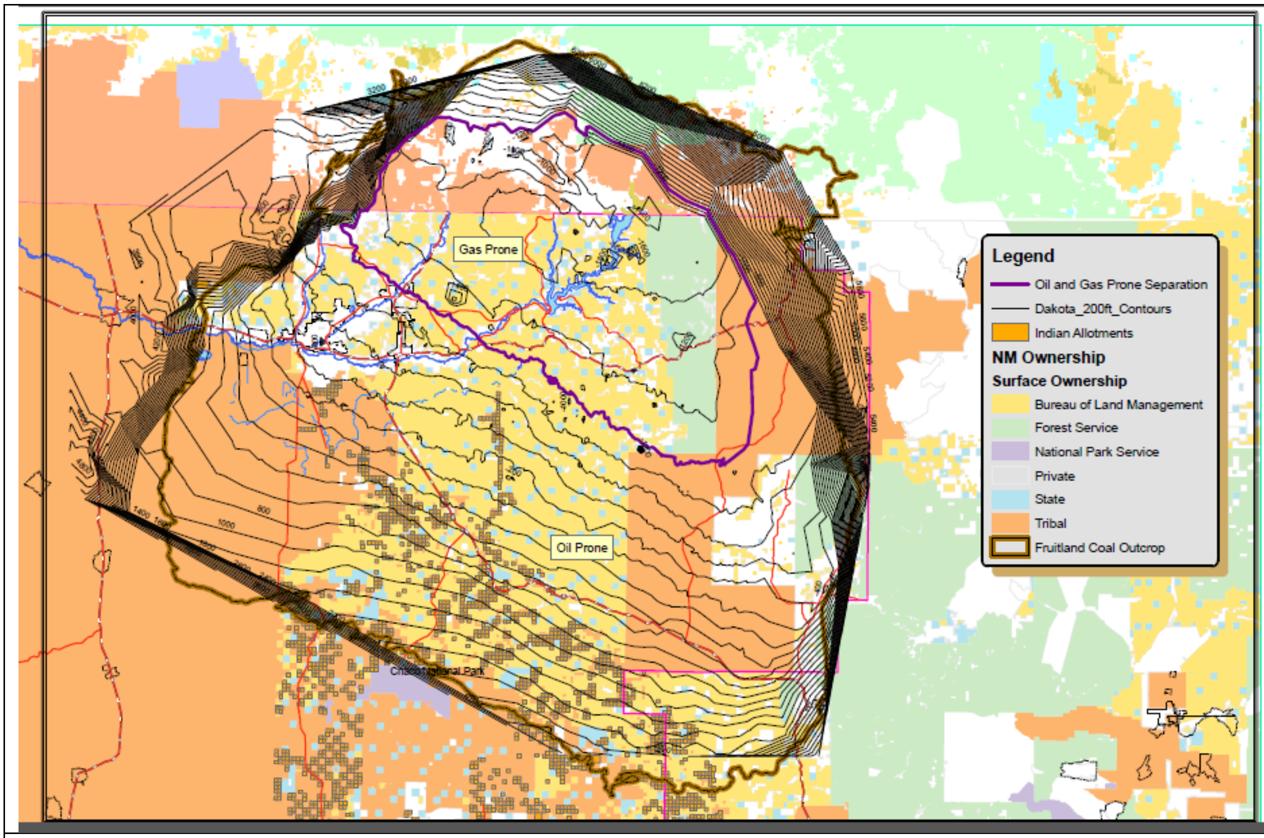


Figure 3-1. Map of oil and gas prone development areas within the Mancos Shale Oil formation primarily in the New Mexico BLM FFO planning area.

3.2.3 Uinta Basin, Utah

Baseline and future year emissions associated with oil and gas development in the Uinta Basin have been estimated by AECOM for the BLM Utah State Office (UTSO[58]) under the UTSO Air Resource Management Study (ARMS). The UTSO ARMS is using a 2010 baseline year. More

[58] http://www.blm.gov/ut/st/en.html

details on the oil and gas emissions for the Uinta Basin are available in the UTSO ARMS documentation[59].

3.2.4 Southwestern Wyoming

Oil and gas development emissions for southwestern Wyoming were based on recent BLM Environmental Impact Statements (EISs), such as the draft EIS for the Continental Divide-Creston Natural Gas Project[60].

3.3 Other Anthropogenic Emissions

Other anthropogenic emissions (i.e., non O&G and BLM authorized mining sources) for the 2021 future year were based on 2020 emission projections compiled by the 3SAQS that were based on EPA's 2020 projections used in the $PM_{2.5}$ NAAQS rulemaking, which used EPA's 2007v5 modeling platform[61]. Emissions associated with oil and gas emissions within the western Colorado, Royal Gorge, North San Juan Basin, Uinta Basin and southwest Wyoming Basin described in Section 3.2 above will be removed from the 2020 3SAQS/NEI to avoid double counting. Similarly, mining emissions on federal lands in the western Colorado BLM planning areas will also be removed from the 2020 NEIs.

Details on the development of the 2020 NEI can be found in the 2020 Emissions Technical Support Document (TSD) for the $PM_{2.5}$ NAAQS rule (EPA, 2012d[62]).

3.4 Emissions that Remain at 2008 Levels

The following emission categories from the 2008 Base Case emissions scenario (see Section 2.5) were assumed to remain unchanged for the 2021 future year emission scenarios:

- Biogenic emissions.
- Fire emissions.
- Lightning emissions.
- Sea salt emissions.
- Windblown dust emissions.
- Emissions from Canada and offshore sources.

3.5 Western Colorado BLM Planning Area Oil and Gas Emissions

The emission calculators were used to generate O&G emissions for the eleven-year period of 2011-2021 for 8 western Colorado BLM Planning Areas:

- Roan Plateau portion of the Colorado River Valley Field Office (CRVFO)
- CRVFO outside of the Roan Plateau
- Grand Junction Field Office (GJFO)
- Kremmling Field Office (KFO)
- Little Snake Field Office)LSFO)

[59] http://www.blm.gov/pgdata/etc/medialib/blm/ut/natural_resources/airQuality.Par.34346.File.dat/UTSO_EmissionsTSD121913.pdf
[60] http://www.blm.gov/wy/st/en/info/NEPA/documents/rfo/cd_creston.html
[61] http://www.epa.gov/ttnchie1/emch/
[62] http://epa.gov/ttn/chief/emch/2007v5/2007v5_2020base_EmisMod_TSD_13dec2012.pdf

- Tres Rios Field Office (TRFO)
- Uncompahgre Field Office (UFO)
- White River Field Office (WRFO)

For each year between 2011-2021, the emissions calculators were used to estimate O&G emissions for upstream (well site) and midstream emission sources and for O&G development on Federal and non-Federal lands within in each of the 8 western Colorado BLM Planning Areas listed above.

3.5.1 2021 High, Low and Medium Development Scenarios

The emissions calculators were used to generate O&G emissions within the 8 western Colorado BLM Planning Areas for 2021 High, Low and Medium Development Scenarios. The High Development Scenario is based on BLM COSOs estimates of RFD O&G future development within these 8 BLM Planning Areas. The Low Development Scenario is based on historical 5-year average O&G development over the 2008-2012 period that was used to grow O&G emissions to each year between 2011-2021. Applicable State and Federal controls are applied to the O&G emissions starting in the year that are required.

The Low Development Scenario assumes 25,710 total active wells in 2021 within the 8 western Colorado BLM Planning Areas with 8,121 wells (32%) on Federal and 17,589 wells (68%) on non-Federal lands. The High Development Scenario assumes 41,033 total active wells, 1.6 times higher than the Low Development Scenario, that are split as 18,347 on Federal (45%) and 22,686 on non-Federal lands. The 2021 Medium Development Scenario has the same number of wells as the High Development Scenario but assumes additional levels of controls. Beyond the application of existing state and federal requirements, additional control of engine and fugitive emission sources for all phases of well-site operation is assumed for wells drilled on Federal land after 2015 as follows:

- ALL development (drilling / completion / fracking) engines will be Tier 4. Tier 4 gen-set standards will be applied for all engines with a horsepower >750; final Tier 4 standards will be applied to all engines with horsepower <750.
- All condensate tank, oil tank, and dehydrator emissions are captured and controlled by VRUs (assumed 95% control efficiency attained by vapor recovery).
- All pneumatic devices are low-bleed or no bleed. Assumed 50% of devices are low-bleed (6 cfh) and 50% of devices are no-bleed.
- Assume that 30% of production engines are powered by electricity (applies to all well-site engines).
- Assume 80% dust control for unpaved road traffic.
- All truck loading emissions are captured and controlled by VRU.

Table 3-1 and Figure 3-2 compare the total emissions from the 8 western Colorado BLM Planning Areas for the 2021 High, Low and Medium Development emission scenarios.

Table 3-2. Comparison of oil and gas emissions from the 8 western Colorado BLM Planning Areas for 2021 High, Low and Medium Development emission scenarios.

Scenario	VOC	CO	NOx	PM10	PM2.5	SO2
All Wells						
Low	44,025	22,715	25,078	4,425	1,270	259
Medium	78,654	45,453	51,983	7,224	2,355	1,145
High	95,427	46,014	56,666	9,482	2,714	1,145
Federal Emissions						
Low	13,950	7,369	7,939	1,233	424	190
Medium	30,254	22,811	26,003	2,763	1,118	971
High	47,007	23,371	29,879	4,996	1,452	972
Non-Federal Emissions						
Low	30,075	15,346	17,139	3,191	846	69
Medium	48,399	22,642	25,979	4,461	1,237	174
High	48,420	22,642	26,787	4,486	1,262	174

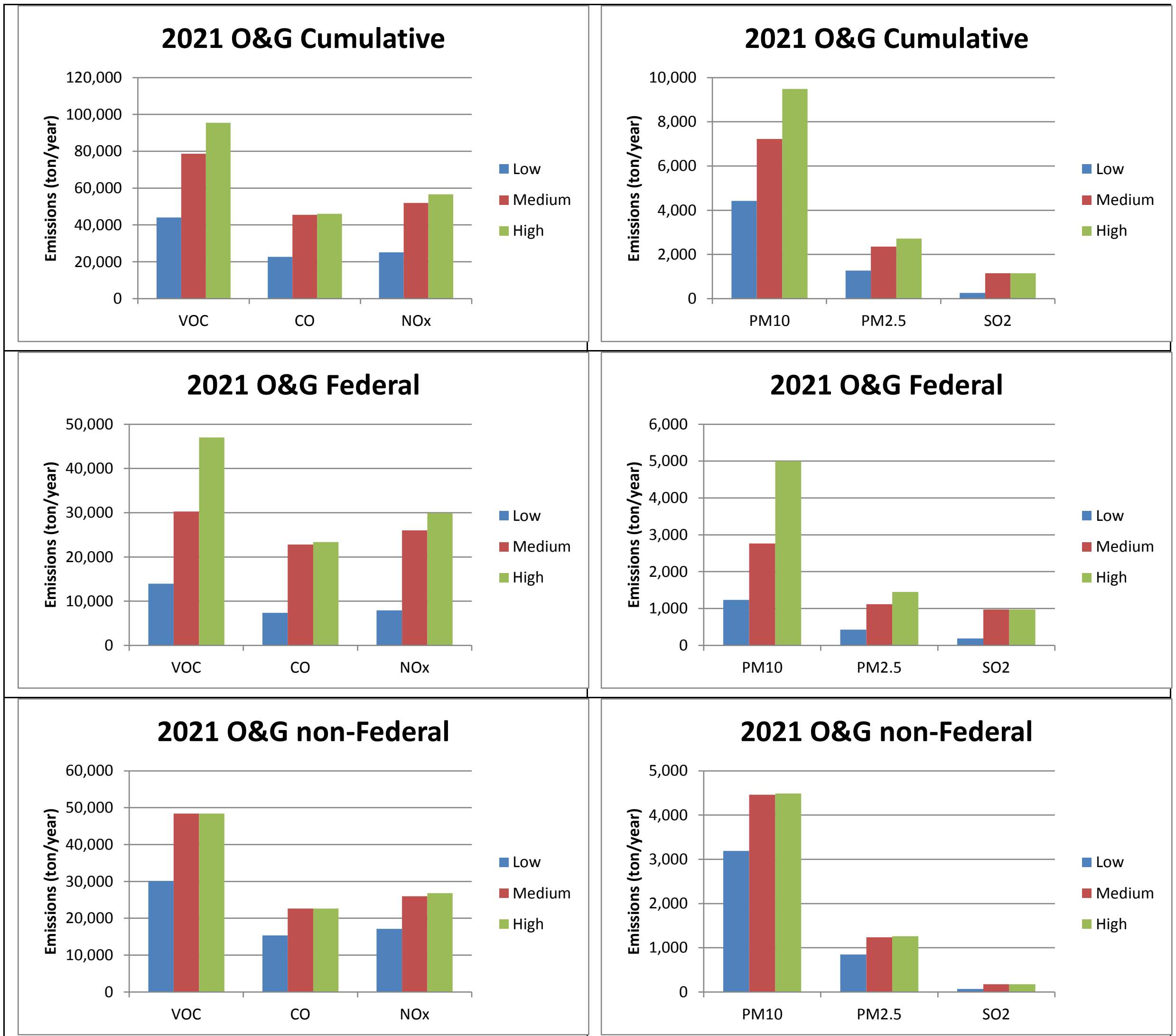


Figure 3-2. Comparison of total oil and gas emissions from the 8 western Colorado BLM Planning Areas for the 2021 High, Low and Medium Development Scenarios.

3.5.2 2021 High Development Scenario

The CARMMS modeling results for the 2021 High Development Scenario are presented in Chapter 5. Results for the other scenarios will be reported in the future. Thus, in this section we summarize the 2021 High Development Scenario emissions for the 8 western Colorado BLM Planning Areas. Figure 3-3 and Table 3-2 display the NOx and VOC O&G emissions for the 8 western Colorado BLM Planning Areas and the 2011 current year emissions and 2021 High Development emissions scenarios stratified by O&G emissions on Federal and non-Federal lands. Summary spreadsheets (not shown) also include emissions stratified by upstream vs. midstream and provide emissions per well as well as results for the Low and Medium Development Scenarios. The CRVFO has the largest O&G NOx (~8,000 TPY) and VOC (~18,000 TPY) emissions of all the western Colorado Field Offices for the 2011 year followed by TRFO, WRFO and GJFO for NOx and WRFO, GJFO and TRFO for VOCs. Across all 8 BLM Planning Areas in 2011, the O&G emissions total was ~22,000 TPY NOx and 35,000 VOC that was split roughly 35 percent on Federal and 65 percent on non-Federal lands. For the 2021 High Development

Scenario there was approximately 2.5 times more NOx and VOC emissions than seen in 2011. There was faster growth in O&G development on Federal lands such that O&G emissions on Federal lands had grown from ~35% in 2011 to ~50% in 2021. In the 2021 High Development Scenario the GJFO has the highest NOx and VOC emissions with the next two highest being WRFO and CRVFO.

Table 3-2. Summary of oil and gas emissions within the 8 western Colorado BLM Planning Areas for the 2011 current year and 2021 High Development emission scenarios.

2011	NOx Emissions (TPY)			VOC Emissions (TPY)		
BLM Area	**Federal**	**non-Fed**	**Total**	**Federal**	**non-Fed**	**Total**
CRVFO (No Roan)	1,036	3,575	4,611	2,596	10,407	13,003
Roan (CRVFO)	1,280	2,158	3,438	1,962	3,356	5,318
GJFO	535	2,976	3,511	634	4,032	4,665
KFO	69	40	108	150	138	288
LSFO	741	189	930	1,493	415	1,907
TRFO	879	4,551	5,431	837	3,243	4,080
UFO	61	76	137	55	65	120
WRFO	3,296	736	4,032	4,433	1,052	5,485
Grand Total	7,896	14,301	22,198	12,159	22,708	34,867
2021 High Scenario	**NOx Emissions (TPY)**			**VOC Emissions (TPY)**		
BLM Area	**Federal**	**non-Fed**	**Total**	**Federal**	**non-Fed**	**Total**
CRVFO (No Roan)	1,679	4,639	6,318	5,070	14,287	19,357
Roan (CRVFO)	1,835	1,856	3,692	2,971	3,425	6,395
GJFO	7,670	10,291	17,961	13,744	20,230	33,974
KFO	236	221	458	424	326	750
LSFO	2,320	1,723	4,042	3,334	2,349	5,683
TRFO	3,386	5,096	8,482	2,289	3,861	6,150
UFO	612	1,067	1,679	620	1,082	1,702
WRFO	12,141	1,893	14,034	18,556	2,859	21,415
Grand Total	29,879	26,787	56,666	47,007	48,420	95,427
Difference	**NOx Emissions (TPY)**			**VOC Emissions (TPY)**		
BLM Area	**Federal**	**non-Fed**	**Total**	**Federal**	**non-Fed**	**Total**
CRVFO (No Roan)	62%	30%	37%	95%	37%	49%
Roan (CRVFO)	43%	-14%	7%	51%	2%	20%
GJFO	1333%	246%	412%	2069%	402%	628%
KFO	244%	455%	322%	183%	136%	160%
LSFO	213%	813%	335%	123%	467%	198%
TRFO	285%	12%	56%	173%	19%	51%
UFO	903%	1302%	1124%	1025%	1565%	1317%
WRFO	268%	157%	248%	319%	172%	290%
Grand Total	278%	87%	155%	287%	113%	174%

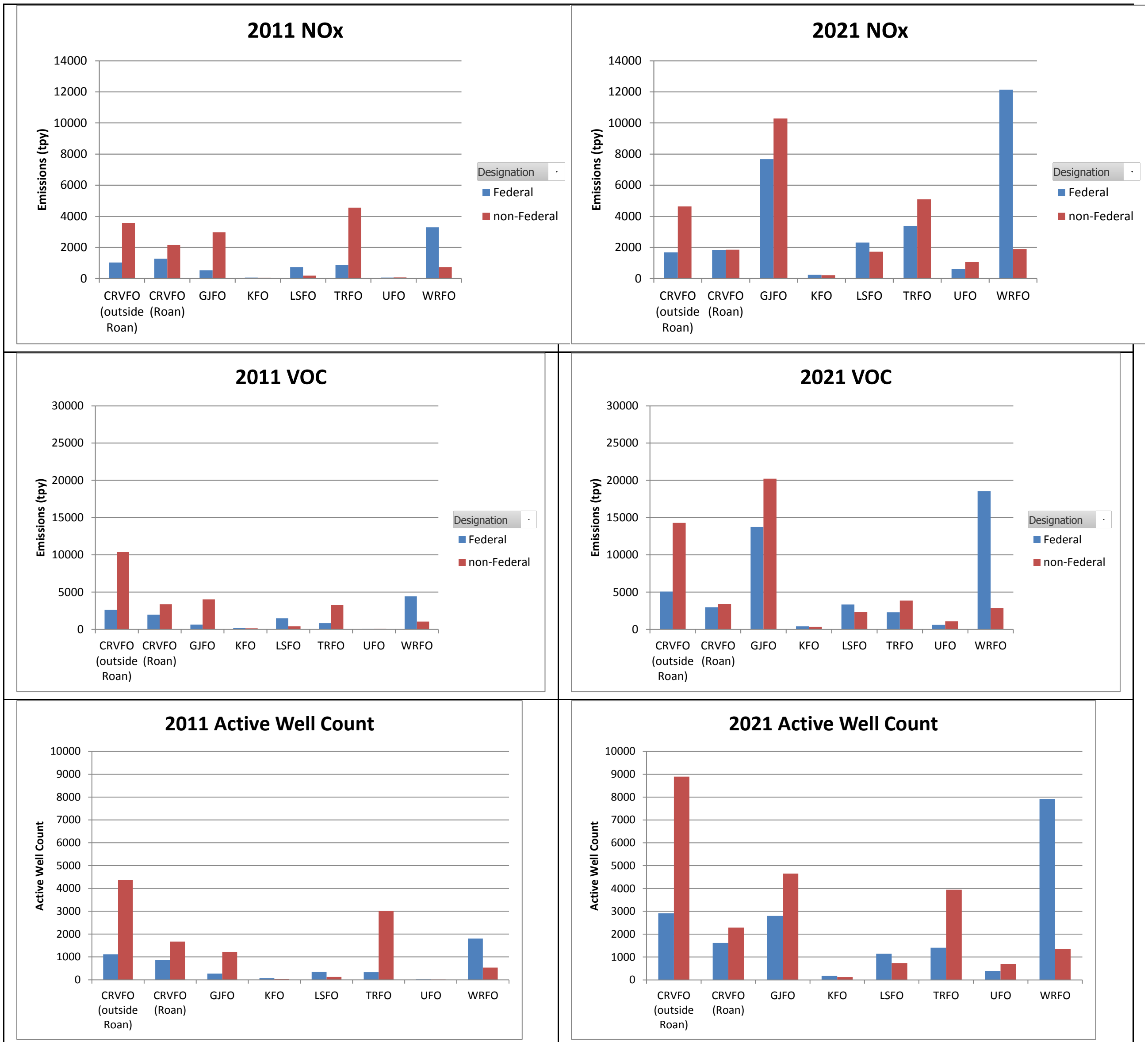


Figure 3-3. NOx, VOC and well counts emissions from oil and gas development within the 8 western Colorado BLM Planning Areas and for the 2011 current and 2021 High Development Scenario emissions scenarios.

3.6 Future Year Emissions Modeling Procedures

The 2021 future year emissions were processed using the SMOKE emissions model in a similar manner as used for the 2008 Base Case emissions scenario described in Section 2.5. One difference in the 2021 SMOKE emissions modeling was that each source category for which separate ozone and particulate matter contributions are needed was processed as a separate stream in the SMOKE emissions modeling. This resulted in many different streams of SMOKE emissions processing for the three 2021 emission scenarios to provide separate source groups so that the AQ/AQRV impacts can be isolated in the source apportionment modeling.

As mentioned in the Section 3.3, the 3SAQS 2020 inventories formed the basis for the 2021 future year model-ready emissions for all non-oil and gas point and area sources except source categories listed in the Section 3.4 which were held unchanged from the base years. The inventory data for the 3SAQS 2020 emissions modeling platform primarily came from the EPA's "2007-Based Platform, Version 5" (2007v5) platform (EPA, 2012d).

3.6.1 Non-Oil and Gas Future-Year Emissions Data

For most of the inventory sectors, the 2020 inventory and ancillary emissions data were obtained directly from the 3SAQS modeling platform, which in turn uses data from EPA's 2007v5 modeling platform. Developed by EPA for use in the $PM_{2.5}$ NAAQS RIA, the 2020 inventory represent the best estimate of future year emissions without the implementation of any new controls necessary to attain the current $PM_{2.5}$ annual and 24-hr (35 $\mu g/m^3$ and 15 $\mu g/m^3$) and ozone 8-hr (75 ppb) standards (EPA, 2012d). These emissions reflect rule promulgated or under reconsideration as of July 2012.

A summary of the 2007v5 modeling platform 2020 inventory is provided below and additional details are available from EPA (EPA, 2012d).

<u>CEM Point:</u> Unit-specific estimates from IPM, version 4.10 with CSAPR and Final MATS.

<u>Non-CEM Point:</u> Projection factors and percent reductions reflect Cross-State Air Pollution Rule (CSAPR) comments and emission reductions due to national rules, control programs, plant closures, consent decrees and settlements and 1997 and 2001 ozone State Implementation Plans in NY, CT, and VA. EPA used projection approaches for corn ethanol and biodiesel plants, refineries and upstream impacts from the Energy Independence and Security Act of 2007 (EISA). Terminal area forecast (TAF) data aggregated to the national level were used for aircraft to account for projected changes in landing/takeoff activity.

<u>Nonpoint/Area:</u> Agricultural sector projection factors for livestock estimates based on expected changes in animal population from 2005 Department of Agriculture data, updated based on personal communication with EPA experts in July 2012; fertilizer application NH3 emissions projections include upstream impacts EISA. Fugitive dust projection factors for dust categories related to livestock estimates based on expected changes in animal population and upstream impacts from EISA. Other nonpoint source projection factors that implement Cross State Air Pollution Rule comments and reflect emission reductions due to control programs. Residential wood combustion projections are based on growth in lower-emitting stoves and a reduction in higher emitting stoves. PFC projection factors reflecting impact of the final Mobile Source Air Toxics (MSAT 2) rule. Upstream impacts from EISA, including post-2007 cellulosic ethanol plants are also reflected.

<u>Off-road Mobile:</u> Other than for California, this sector uses data from a run of NMIM that utilized NONROAD2008a, using future-year equipment population estimates and control programs to the year 2020 and using national level inputs. Final controls from the final locomotive-marine and small spark ignition OTAQ rules are included. California-specific data were provided by CARB.

Aircraft/locomotive/marine: For all states except California, projection factors for Class 1 and Class 2 commercial marine and locomotives, which reflect final locomotive-marine controls. California projected year-2020 inventory data were provided by CARB.

Offshore shipping: Base-year 2007 emissions grown and controlled to 2020, incorporating controls based on Emissions Control Area (ECA) and International Marine Organization (IMO) global NOX and SO2 controls.

On-road Mobile, not including refueling: MOVES2010b emissions factors for year 2020 were developed using the same representative counties, state-supplied data, meteorology, and procedures that were used to produce the 2007 emission factors. California-specific data were provided by CARB. Other than California, this sector includes all non-refueling on-road mobile emissions (exhaust, evaporative, evaporative permeation, brake wear and tire wear modes).

On-road Refueling: Uses the same projection and processing approach as the on-road sector, except for California where EPA projected using MOVES2010b and did not include CARB data.

Canada Sources: Held constant and 2006 levels.

Mexico Sources: Projections from 1999 to 2018.

The ancillary data (spatial/temporal/chemical) were held unchanged from the 3SAQS platform for preparing the 2021 emissions for CAMx. In the 3SAQS platform, the base sets of ancillary data were taken directly from the EPA 2007v5 modeling platform. The 3SAQS made targeted improvements to the ancillary files for counties in the 3-state study region (Figure 3-4). The improvements were focused on the assignments of spatial/chemical/temporal profiles to inventory sources and on developing profiles that best represent the emissions patterns in the 3-state study region.

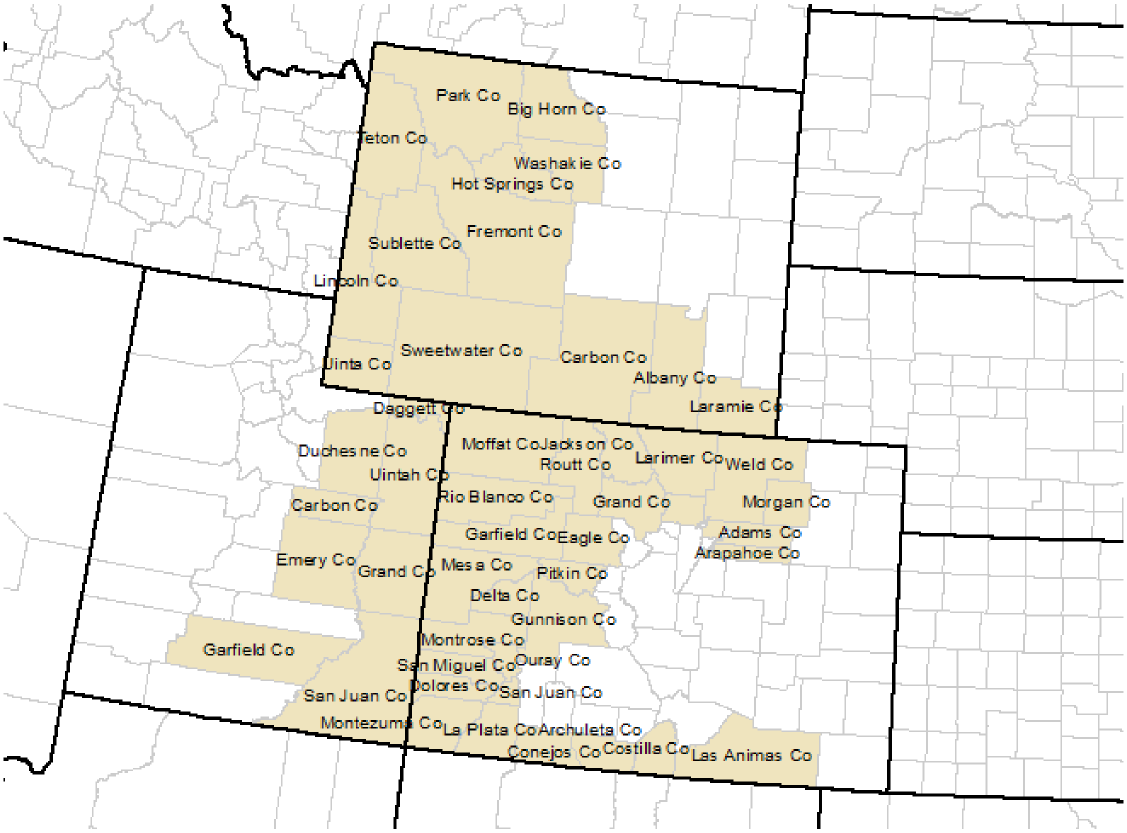


Figure 3-4. Preliminary list of counties in the 3-state study region.

The 3SAQS improvements for the CO/UT/WY counties include the following:

Utah

- Updated the 2007v5 spatial surrogates for land cover and building square footage with NLCD2006 and FEMA-HAZUS data
- Changed the ATV/ORV/Snowmobile surrogate assignment from rural land area to forest land
- Changed the livestock surrogate assignment from total agricultural land to pasture land
- Changed the fertilizer surrogate assignment from total agricultural land to crop land
- Created a state-specific, year 2011 monthly temporal profile for residential natural gas heating fuel use with Energy Information Administration data (Figure 6-32).
- Used point locations of rest areas and truck stops to allocation MOVES extended idling emissions to the modeling grid

Colorado

- Updated the 2007v5 spatial surrogates for land cover and building square footage with NLCD2006 and FEMA-HAZUS data
- Changed the ATV/ORV/Snowmobile surrogate assignment from rural land area to forest land

- Created CAFO spatial surrogates from data provided by CDPHE for livestock ammonia sources
- Changed the livestock surrogate assignment from total agricultural land to pasture land
- Changed the fertilizer surrogate assignment from total agricultural land to crop land
- Created a state-specific, year 2011 monthly temporal profile for residential natural gas heating fuel use with Energy Information Administration data (Figure 3-5).
- Developed 2008 vehicle miles traveled (VMT)-based spatial surrogates for on-road mobile sources. Figure 3-6 compares the U.S. Census year 2010 TIGER line roadway data with link-based VMT data from CO.
- Used point locations of rest areas and truck stops to allocation MOVES extended idling emissions to the modeling grid

Wyoming

- Updated the NEI08v2 spatial surrogates for land cover and building square footage with NLCD2006 and FEMA-HAZUS data
- Changed the ATV/ORV/Snowmobile surrogate assignment from rural land area to forest land
- Changed the livestock surrogate assignment from total agricultural land to pasture land
- Changed the fertilizer surrogate assignment from total agricultural land to crop land
- Created a state-specific, year 2011 monthly temporal profile for residential natural gas heating fuel use with Energy Information Administration data (Figure 3-5).
- Developed confined animal feeding operation (CAFO) spatial surrogates for livestock sources. The CAFOs locations data were provided by the state of Wyoming (Figure 3-7). The 3SAQS generated WY livestock surrogates for cattle, poultry, and swine.
- Used point locations of rest areas and truck stops to allocation MOVES extended idling emissions to the modeling grid

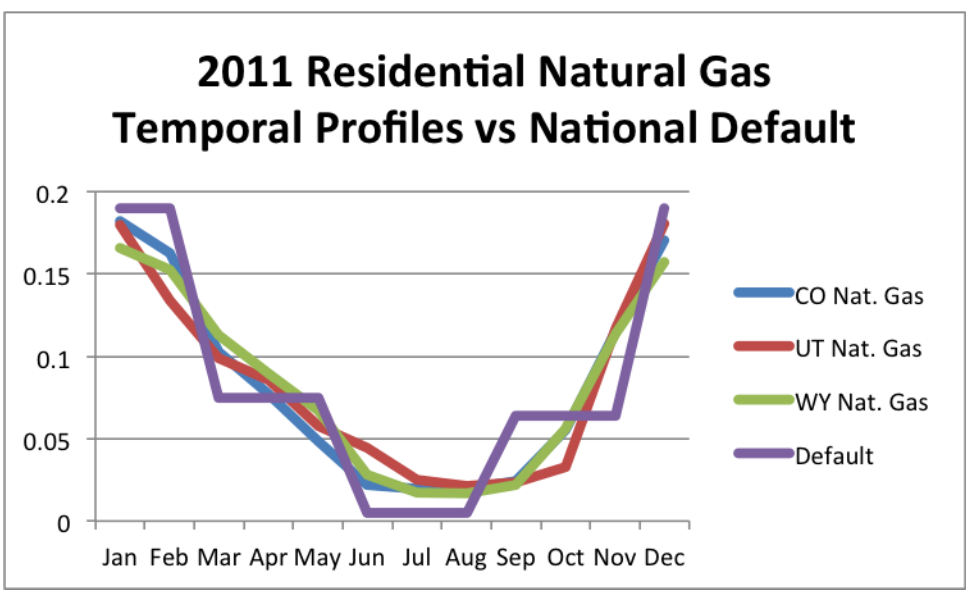


Figure 3-5. 3SAQS 2011 residential natural gas consumption monthly temporal profiles.

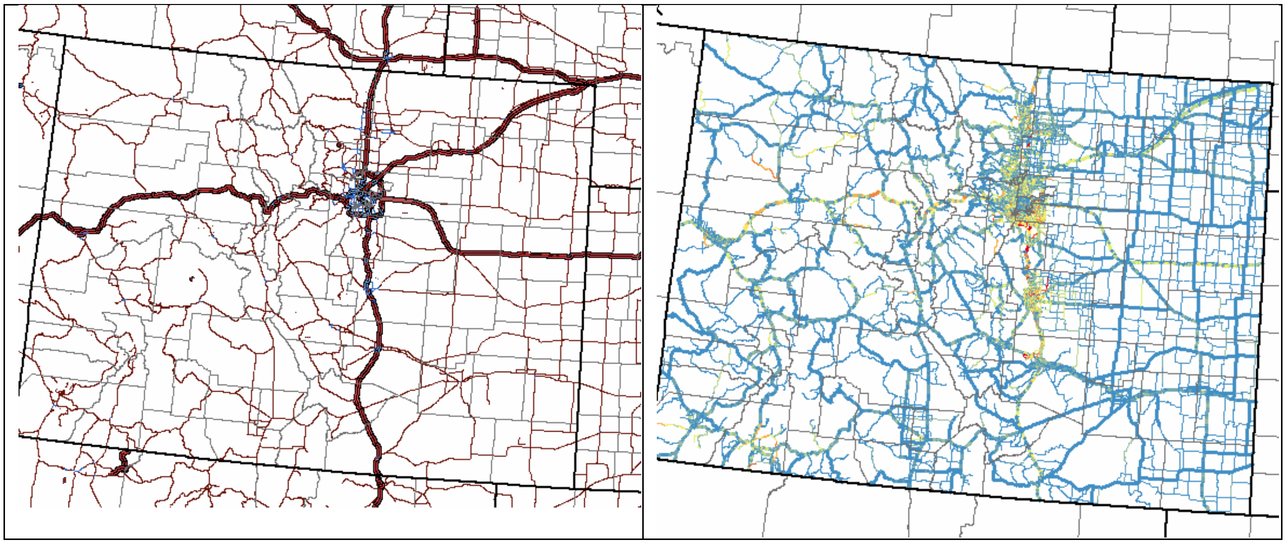


Figure 3-6. Colorado roadway spatial data improvement plots. Left: TIGER 2010 Shapefile of urban/rural primary/secondary roads. Right: CO 2008 VMT-based roadways.

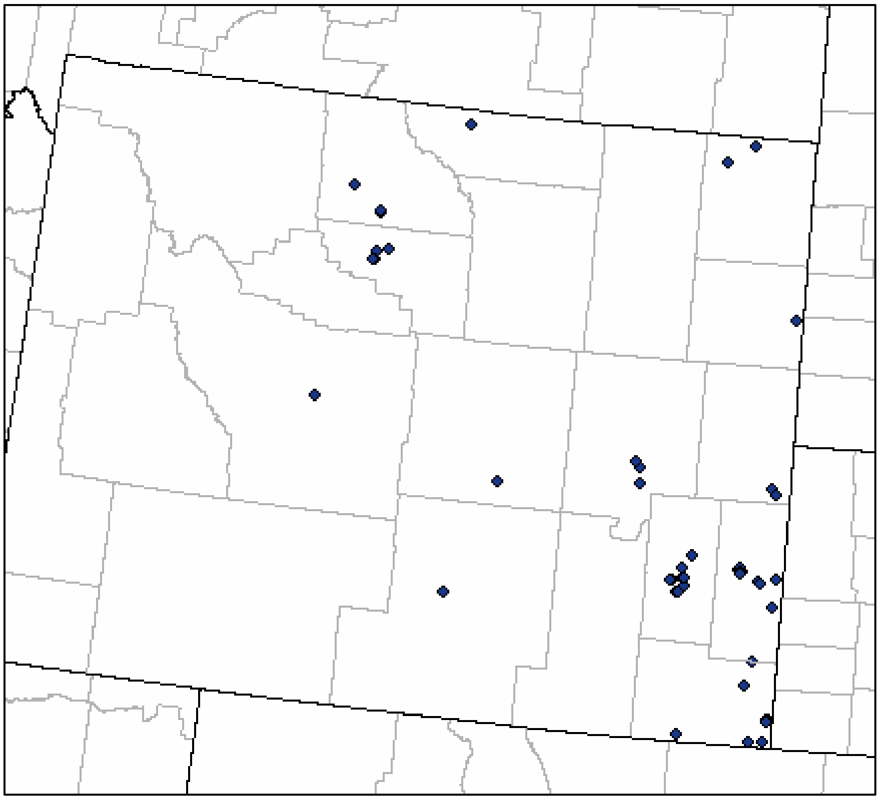


Figure 3-7. Wyoming CAFO locations.

3.6.2 Oil and Gas Future-Year Emissions Data

For oil and gas sources, ENVIRON developed emissions inventories for the western Colorado BLM planning areas as described in Section 3.1 and South San Juan basin, NM as described in Section 3.2.2. The oil and gas emissions for all other planning areas were provided by BLM as described in Section 3.2.

For oil and gas sources within 14 BLM planning areas, emissions were divided into existing and RFD (new) source categories to facilitate CAMx source apportionment processing. The RFD sources were further divided into oil and gas development on the BLM-authorized land (Federal) and other (non-Federal). The South San Juan basin existing emissions were obtained from the WRAP Phase III midterm projection. For sources outside of 14 BLM planning areas, the 2020 3SAQS inventory was used.

For processing oil and gas emissions, we developed ancillary data (spatial/temporal/chemical) specific to planning areas. The area-specific spatial allocation profiles were developed from the data provided by BLM and chemical speciation profiles were prepared from the gas composition available in the emission calculator. Table 3-3 provides a list of speciation and gridding profiles developed by planning areas. The conventional (CG) and CBM gas speciation profile are assigned to source categories associated with the respective well type. For spatial allocation, gridding profiles were developed for each well type (i.e., conventional, CBM) and land type (Federal, non-Federal) combination.

Table 3-3. Source of VOC speciation profile and spatial surrogates used for gridding oil and gas emissions in the 14 CO/NM BLM Planning Areas.

Source Region	Speciation Profiles	Gridding Profiles
Colorado		
Colorado River Valley, without Roan	CRV{CG}	CRVFO {CG}{Fed,non-Fed}
Grand Junction FO	GJ {CBM,CG,SG}	GJFO {CG,CBM}{Fed,non-Fed}
Kremmling FO	K {CBM,CG,CO}	KFO shapefile
Little Snake FO	LS {CG,CO}	CRVFO {CG}{Fed,non-Fed}
Roan Plateau	CRV{CG}	CRVFO_Roan_Plateau.
Tres Rios FO	TR {CBM,CG,CO,SHL}	TRFO {CG,CBM}{Fed,non-Fed}
Uncompahgre FO	U {CBM,CG}	UFO {CG,CBM}{Fed,non-Fed}
White River FO	WR {CG,CO}	WRVFO {CG}{Fed,non-Fed}
Pawnee National Grasslands	DJ{FLA ,VNT}	RGFO {CG}{Fed}
Royal Gorge FO Area1	DJ{FLA ,VNT}	RGFO {CG}{Fed,non-Fed}
Royal Gorge FO Area2	DJ{FLA ,VNT}	RGFO {CG}{Fed,non-Fed}
Royal Gorge FO Area3	DJ{FLA ,VNT}	RGFO {CG}{Fed,non-Fed}
Royal Gorge FO Area4	DJ{FLA ,VNT}	RGFO {CG}{Fed,non-Fed}
New Mexico		
Farmington FO	MAN{SG, SO}	Shapefile

3.6.3 Mining Future-Year Emissions Data

For mining sources, emissions were estimated for coal and uranium mines on Federal lands in the western Colorado BLM Planning Areas. The emissions for mines on Federal lands were estimated based on the CDPHE APEN database and available EISs and EAs. The mining emissions not on federal lands were obtained from the 2020 3SAQS inventory.

The estimated coal mining sources were consolidated with the 2020 3SAQS inventory to avoid potential double counting. The western Colorado uranium mining emissions were modeled as "area" and spatially allocated using spatial surrogates developed from the data provided by BLM in a shapefile format.

3.7 Emissions Modeling Results

Table 3-4 lists the total NO_X, VOC and $PM_{2.5}$ emissions for the 20 Source Categories used in the CAMx 2021 High Development Scenario source apportionment simulation (see Section 4.1 and Table 4-1). These emissions were obtained from a CAMx source apportionment diagnostic is output for an example day (July 1, 2008). Note that temporal adjustments are applied in the SMOKE emissions modeling so the example day emissions in Table 3-4 will not match the annual emissions in Table 3-2. For new Federal O&G within the 14 BLM Planning Areas, the WRFO has the most NO_X emissions (30.7 tons per day, TPD) followed by GJFO (19.9 TPD), FFO (9.1 TPD) and TRFO (7.3 TPD). Total 2021 O&G NO_X emissions in the 14 BLM Planning Areas is 488.5 TPD that is split 18 percent new Federal (88.9 TPD), 37 percent new non-Federal (178.7 TPD) and 45 percent existing O&G emissions (220.9 TPD). Outside of the 14 BLM Planning Areas, there is an additional 163.5 TPD O&G NO_X emissions for a total 2021 O&G NO_X emissions across the entire 4 km CARMMS domain of 652.0 TPD that represents 34.3 percent of the total anthropogenic and 29.3 percent of the total (anthropogenic plus natural) NO_X emissions in the 4 km domain.

Total O&G VOC emissions in the 4 km CARMMS domain is 3,100.7 TPD that represents 73.4 percent of the total anthropogenic and 23 percent of the total anthropogenic and natural VOC emissions across the domain. Natural VOC emissions represent 68.6 percent of the VOC emissions across the 4 km CARMMS domain on this day. Note that biogenic emissions are highly day-specific with higher emissions under warmer temperatures and higher light intensity, this the contributions of biogenic VOC emissions to the total on this example summer day (68.6 percent) would be expected to be lower on a cooler day. Also note that the VOC emissions in Table 3-4 were obtained from the Carbon Bond chemical mechanism species that will be different than the VOC species input into the SMOKE emissions modeling system (for example, includes ethane).

With one exception, SO_2 emissions from Federal O&G within the 14 BLM Planning Areas is very low. The exception is the WRFO Planning Area where the 2.5 TPD SO_2 emissions represents 95 percent of the 2.6 TPD SO_2 emissions from all of the 14 BLM Planning Areas combined. Total O&G SO_2 emissions across the CARMMS domain is 16.6 TPD that is primarily (75 percent) due to O&G from outside of the 14 BLM Planning Areas, which includes the Uinta Basin where some sour gas reserves occur.

Total $PM_{2.5}$ emissions from O&G in the 14 BLM Planning Areas is 21.4 TPD of which over half (58 percent) is due to nob-Federal O&G and the rest approximately split equally between Federal and existing O&G. Mining within the 14 BLM Planning Areas contributes 19.1 TPD. By far the largest contribution of primary $PM_{2.5}$ emissions is the other (non O&G) anthropogenic emissions category that contributes 80 percent of the region-wide total with natural emissions contributing most of the rest (15 percent) on this day, which is due to wildfires.

Figure 3-8 displays spatial maps of NO_X, VOC and $PM_{2.5}$ emissions across the 4 km CARMMS domain by different source types. Figure 3-8a displays the total new Federal and new non-Federal O&G emissions across the 14 CO/NM BLM Planning Areas that shows a mixture of Federal and non-Federal O&G emissions in the western Colorado Planning Areas. Most of the new O&G emissions in the eastern Colorado Planning Areas (e.g., Weld County) is due to non-Federal O&G, except for the development within the Pawnee Grassland Planning Area. The differences in the new Federal and non-Federal O&G emissions for the Mancos Shale Development area in northern New Mexico reflects the assumption that new O&G was split 70 percent Federal and 30 percent non-Federal.

Figure 3-8b top panel displays the spatial distribution of emissions that combines the existing O&G within the 14 CO/NM BLM Planning Areas with the remainder O&G (new Federal and non-Federal plus existing) within the 4 km CARMMS domain but outside of the 14 CO/NM BLM Planning Areas. In addition to the familiar Basins within the 14 CO/NM Planning Areas (Denver-Julesburg, Piceance and North and South San Juan), the Uinta Basin is clearly evident along with O&G emissions in southwest Wyoming and in the Texas panhandle. Mining within the Colorado BLM Planning Areas consist of mainly isolated grid cells that can have very high $PM_{2.5}$ emissions (Figure 3-8b, bottom panel). Figure 3-8c displays the other (remainder) anthropogenic emissions and natural emissions. Roadways and the major urban areas of Denver, Salt Lake City, Colorado Springs and Albuquerque are clearly evident in the other anthropogenic emissions NO_X and VOC maps. Whereas the spatial maps of other anthropogenic $PM_{2.5}$ emissions is more reflective of agricultural sources. Natural VOC emissions are dominated by forested areas, whereas the natural NO_X emissions are higher in agricultural areas and the locations of fires in 2008.

Table 3-4a. Total emissions (tons per day) for each Source Category (see Table 4-1) and combinations of Source Categories for the 2021 High development Scenario from the CAMx source apportionment diagnostic output file for July 1, 2008.

Number	Category	NO_X	VOC	SO_2	$PM_{2.5}$
1	Biogenics	324.00	6781.80	0.99	131.03
2	LSFO	5.54	12.70	0.04	0.20
3	WRFO	30.70	74.40	2.47	1.62
4	CRVFO	3.58	16.60	0.01	0.19
5	RPPA	3.40	7.48	0.00	0.13
6	GJFO	19.90	49.40	0.04	0.85
7	UFO	1.60	2.37	0.00	0.10
8	TRFO	7.28	4.69	0.00	0.34
9	KFO	0.48	1.13	0.00	0.03
10	RGFO #1	0.82	2.38	0.00	0.08
11	PGPA	2.52	7.31	0.01	0.25
12	RGFO #2	3.10	4.16	0.00	0.06
13	RGFO #3	0.61	0.21	0.00	0.01
14	RGFO #4	0.25	2.58	0.00	0.04
15	FFO	9.07	23.90	0.01	0.86
16	New non-Fed 14 BLM PAs	178.70	624.00	0.81	12.42
17	Existing O&G 14 BLM PAs	220.90	624.50	0.69	4.24
18	Mining 14 BLM PAs	2.53	0.16	0.03	19.12
19	O&G outside 14 BLM PAs	163.50	817.30	12.50	7.03
20	Remaining Anthropogenic	1244.70	825.40	239.50	698.42
	14 BLM PAs Fed O&G	88.85	209.30	2.60	4.76
	14 PAs Total O&G	488.45	1457.80	4.09	21.42
	Total O&G	651.95	2275.10	16.59	28.44
	Total Anthropogenic	1899.19	3100.67	256.12	745.99
	Total Anthropogenic and Biogenic	2223.19	9882.47	257.11	877.02

Table 3-4b. Percent contribution to total anthropogenic emissions for each Source Category (see Table 4-1) and combinations of Source Categories for the 2021 High development Scenario from the CAMx source apportionment diagnostic output file for July 1, 2008.

Number	Category	NO_X	VOC	SO_2	$PM_{2.5}$
1	Biogenics				
2	LSFO	0.29%	0.41%	0.02%	0.03%
3	WRFO	1.62%	2.40%	0.96%	0.22%
4	CRVFO	0.19%	0.54%	0.00%	0.03%
5	RPPA	0.18%	0.24%	0.00%	0.02%
6	GJFO	1.05%	1.59%	0.02%	0.11%
7	UFO	0.08%	0.08%	0.00%	0.01%
8	TRFO	0.38%	0.15%	0.00%	0.05%
9	KFO	0.03%	0.04%	0.00%	0.00%
10	RGFO #1	0.04%	0.08%	0.00%	0.01%
11	PGPA	0.13%	0.24%	0.00%	0.03%
12	RGFO #2	0.16%	0.13%	0.00%	0.01%
13	RGFO #3	0.03%	0.01%	0.00%	0.00%
14	RGFO #4	0.01%	0.08%	0.00%	0.01%
15	FFO	0.48%	0.77%	0.01%	0.11%
16	New non-Fed 14 BLM PAs	9.41%	20.12%	0.32%	1.66%
17	Existing O&G 14 BLM PAs	11.63%	20.14%	0.27%	0.57%
18	Mining 14 BLM PAs	0.13%	0.01%	0.01%	2.56%
19	O&G outside 14 BLM PAs	8.61%	26.36%	4.88%	0.94%
20	Remaining Anthropogenic	65.54%	26.62%	93.51%	93.62%
	14 BLM PAs Fed O&G	4.68%	6.75%	1.01%	0.64%
	14 PAs Total O&G	25.72%	47.02%	1.60%	2.87%
	Total O&G	34.33%	73.37%	6.48%	3.81%
	Total Anthropogenic	100.00%	100.00%	100.00%	100.00%
	Total Anthropogenic and biogenic				

Table 3-4c. Percent contribution to total anthropogenic plus biogenic emissions for each Source Category (see Table 4-1) and combinations of Source Categories for the 2021 High development Scenario from the CAMx source apportionment diagnostic output file for July 1, 2008.

Number	Category	NO_X	VOC	SO_2	$PM_{2.5}$
1	Biogenics	14.57%	68.62%	0.38%	14.94%
2	LSFO	0.25%	0.13%	0.02%	0.02%
3	WRFO	1.38%	0.75%	0.96%	0.19%
4	CRVFO	0.16%	0.17%	0.00%	0.02%
5	RPPA	0.15%	0.08%	0.00%	0.01%
6	GJFO	0.90%	0.50%	0.02%	0.10%
7	UFO	0.07%	0.02%	0.00%	0.01%
8	TRFO	0.33%	0.05%	0.00%	0.04%
9	KFO	0.02%	0.01%	0.00%	0.00%
10	RGFO #1	0.04%	0.02%	0.00%	0.01%
11	PGPA	0.11%	0.07%	0.00%	0.03%
12	RGFO #2	0.14%	0.04%	0.00%	0.01%
13	RGFO #3	0.03%	0.00%	0.00%	0.00%
14	RGFO #4	0.01%	0.03%	0.00%	0.01%
15	FFO	0.41%	0.24%	0.01%	0.10%
16	New non-Fed 14 BLM PAs	8.04%	6.31%	0.31%	1.42%
17	Existing O&G 14 BLM PAs	9.94%	6.32%	0.27%	0.48%
18	Mining 14 BLM PAs	0.11%	0.00%	0.01%	2.18%
19	O&G outside 14 BLM PAs	7.35%	8.27%	4.86%	0.80%
20	Remaining Anthropogenic	55.99%	8.35%	93.15%	79.64%
	14 BLM PAs Fed O&G	4.00%	2.12%	1.01%	0.54%
	14 PAs Total O&G	21.97%	14.75%	1.59%	2.44%
	Total O&G	29.33%	23.02%	6.45%	3.24%
	Total Anthro	85.43%	31.38%	99.62%	85.06%
	Total Total	100.00%	100.00%	100.00%	100.00%

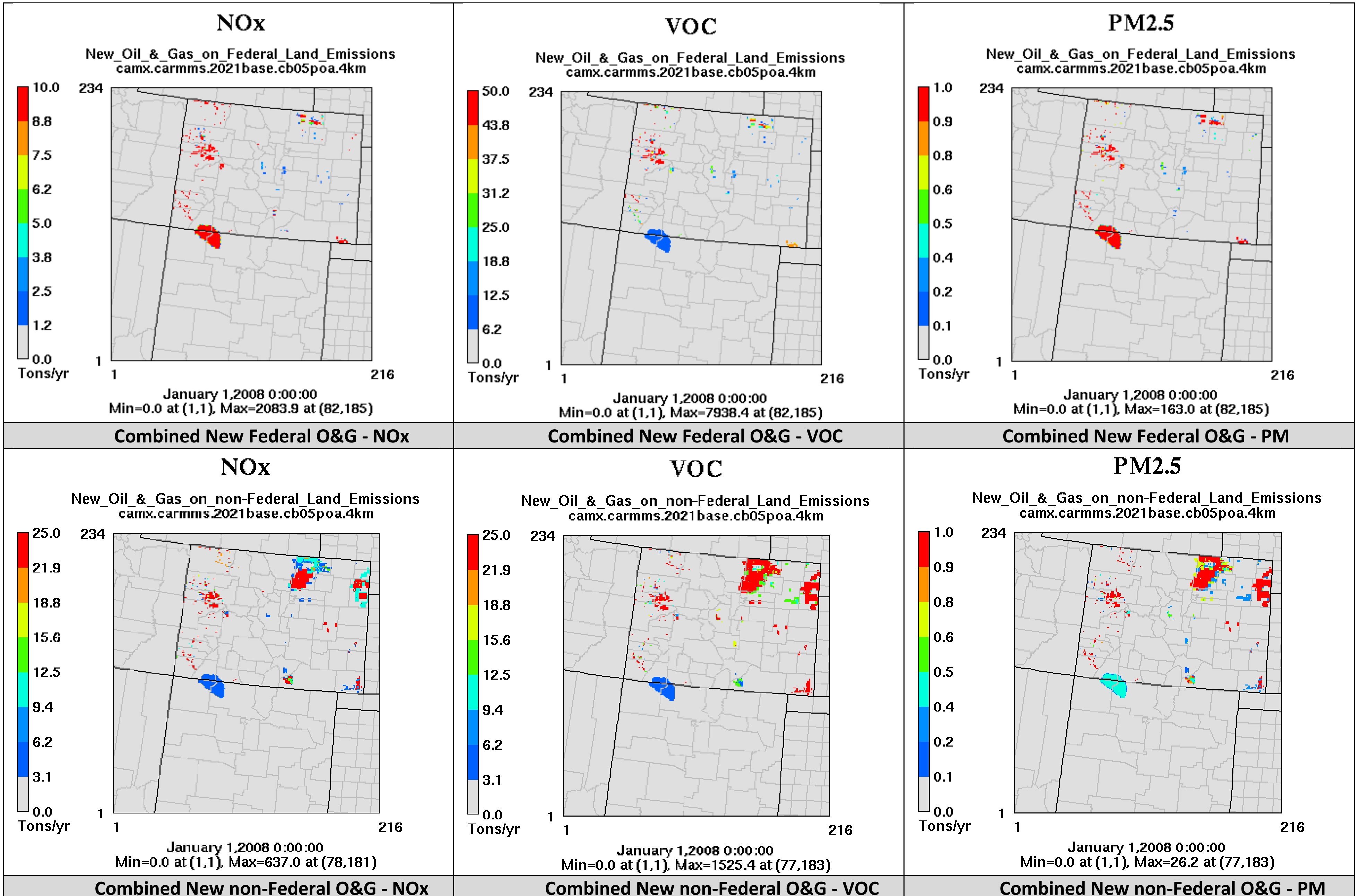
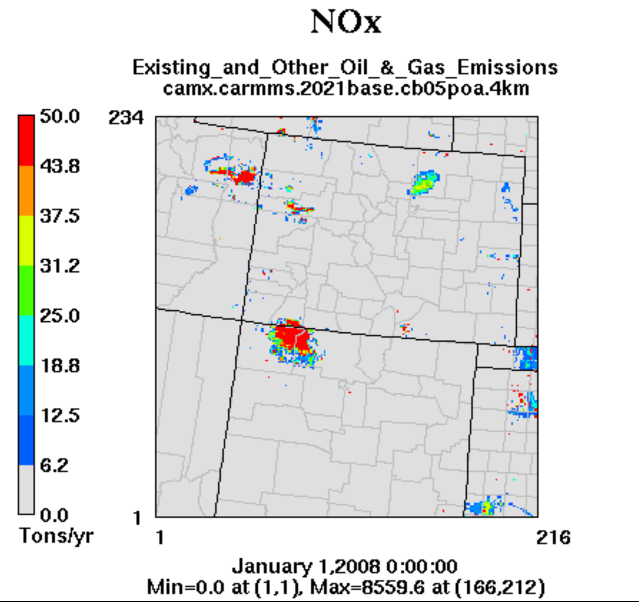
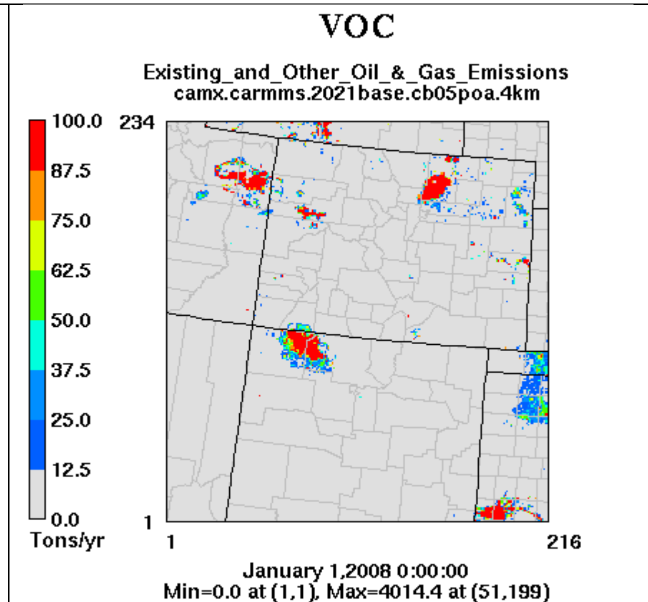
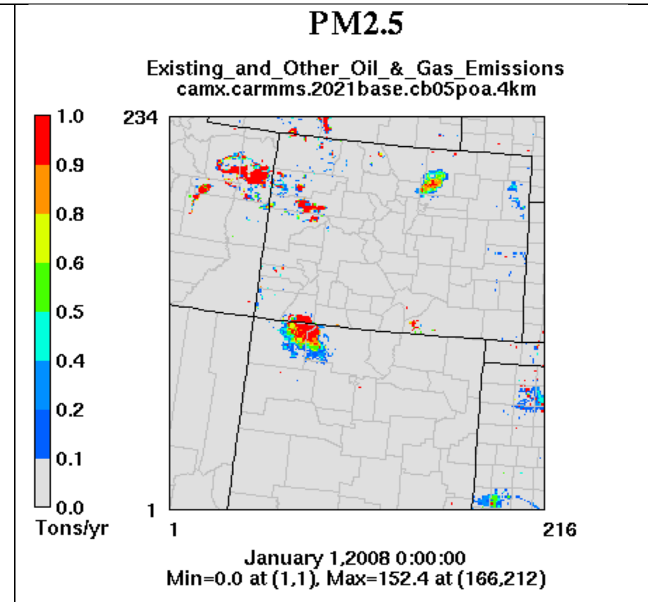


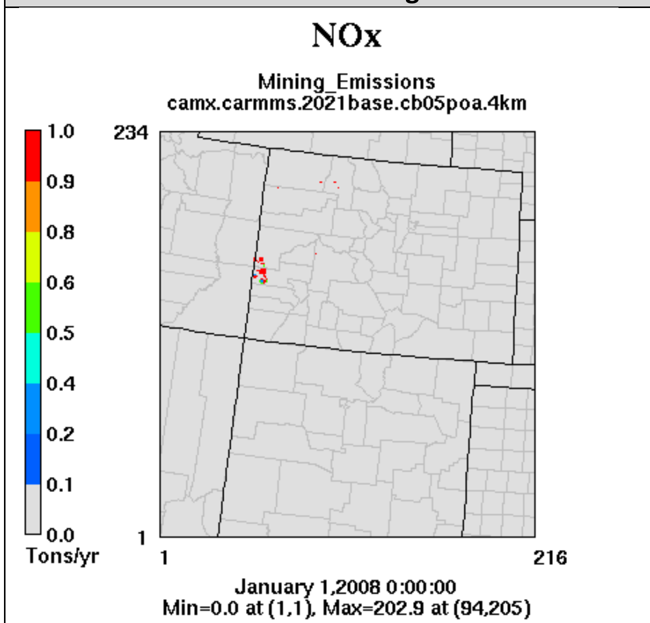
Figure 3-8a. Spatial distribution of Federal (top) and non-Federal oil and gas NO_X, VOC and $PM_{2.5}$ emissions (tons per year) for the 14 BLM Planning Areas.

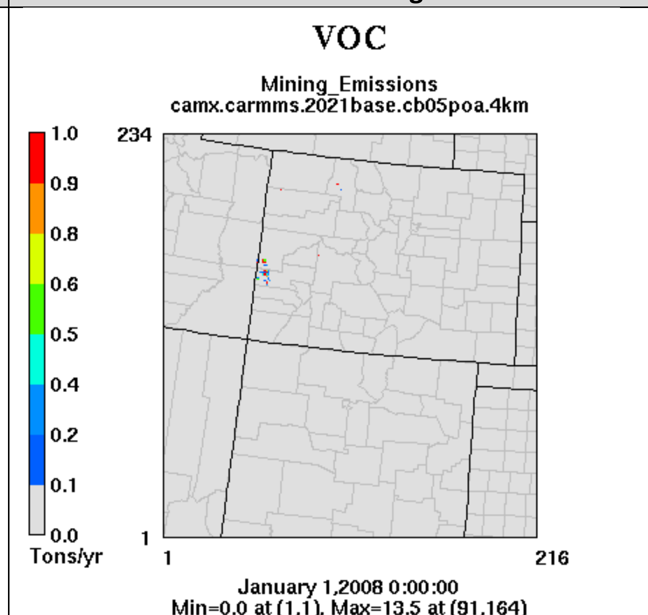


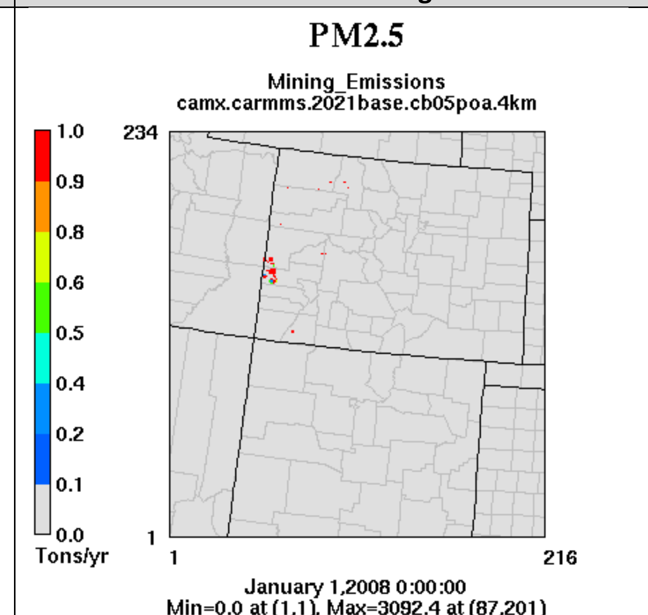




Combined Existing O&G - NOx | Combined Existing O&G - VOC | Combined Existing O&G – PM

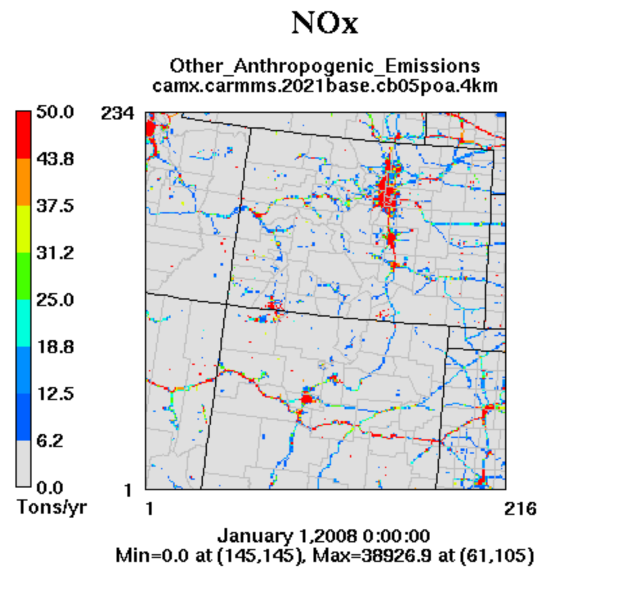


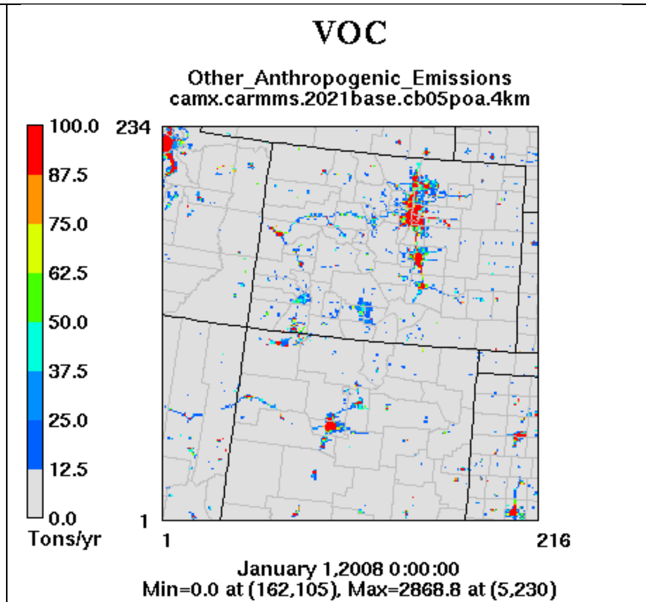


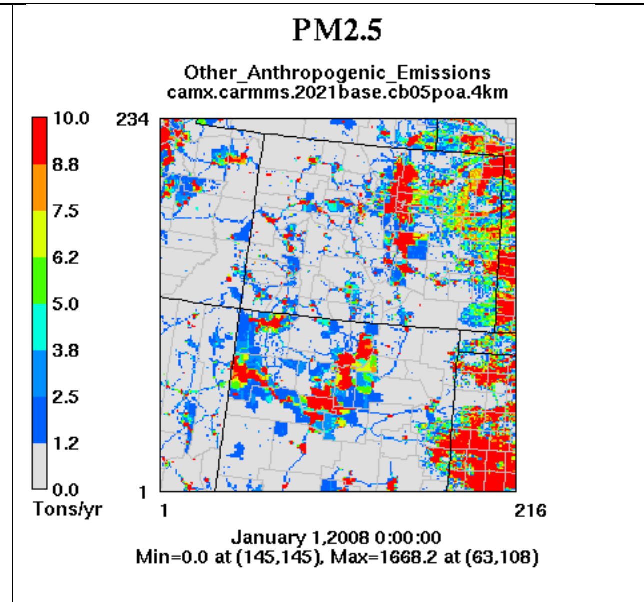


Mining - NOx | Mining - VOC | Mining - PM

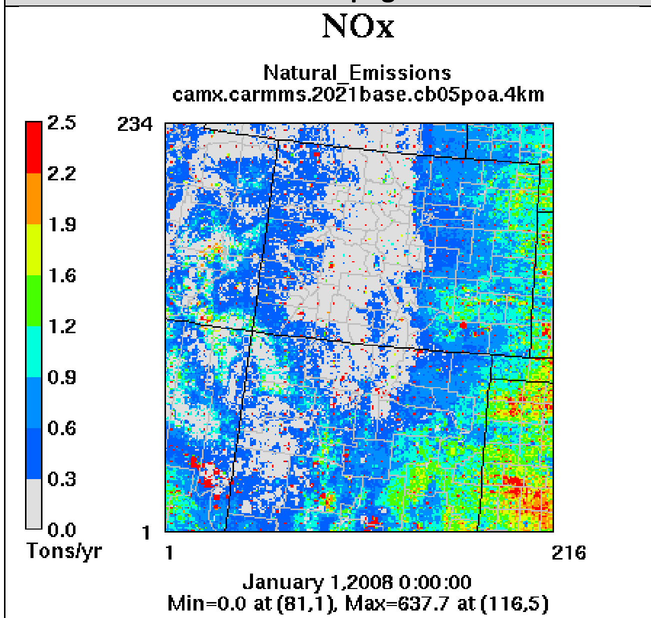
Figure 3-8b. Spatial distribution of Existing oil and gas (top) and mining on Federal lands NO_X, VOC and $PM_{2.5}$ emissions (tons per year) for the 14 BLM Planning Areas.

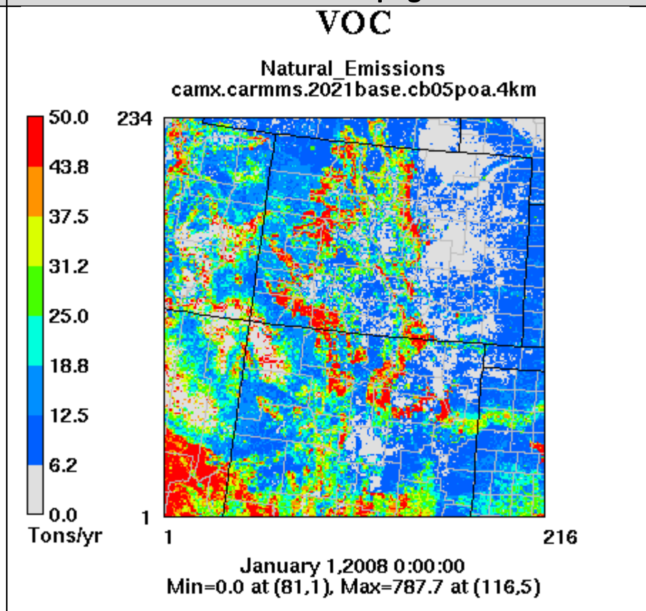


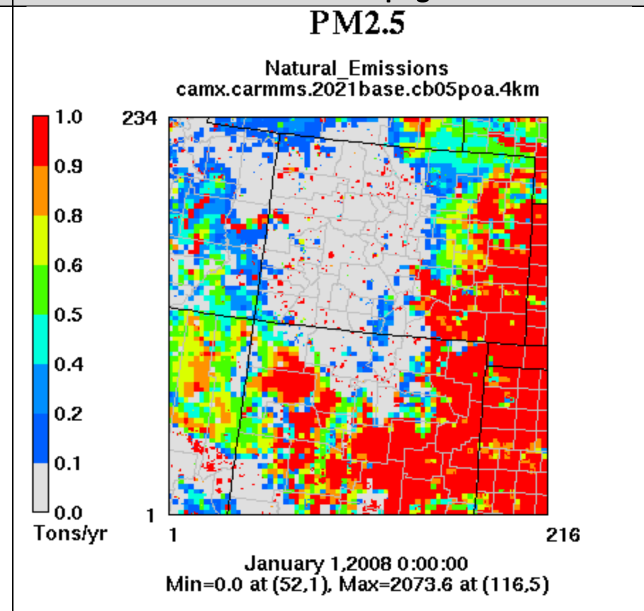




Other Anthropogenic - NOx | Other Anthropogenic - VOC | Other Anthropogenic – PM







Natural - NOx | Natural - VOC | Natural - PM

Figure 3-8c. Spatial distribution of other anthropogenic (top) and natural (biogenic, fires, lightning, sea salt and windblown dust) NO_X, VOC and $PM_{2.5}$ emissions (tons per year) for the 14 BLM Planning Areas.

4.0 FUTURE YEAR MODELING APPROACH

The CAMx source apportionment tool was used to obtain the separate contributions of BLM authorized oil and gas development on Federal lands within 13 Colorado BLM Planning Areas plus the Mancos Shale Development in northern New Mexico. This draft report addresses the contributions to air quality (AQ) and air quality related value (AQRV) impacts associated with the 2021 High Development Scenario. 2021 results for the Low and Medium Development Scenario will be reported on in the future. The following sections describe how the CARMMS 2021 High Development Scenario CAMx source apportionment modeling was conducted and analyzed with results presented in Chapter 5.

4.1 CARMMS Source Apportionment Modeling Approach

The CAMx Anthropogenic Precursor Culpability Assessment (APCA) versions of the Ozone Source Apportionment Technology (OSAT) and Particulate Source Apportionment Technology (PSAT) was used to obtain AQ and AQRV contributions due to BLM-authorized new oil and gas on Federal lands separately for each of the Colorado BLM Planning Areas and the Mancos Shale O&G development within the New Mexico Farmington District Office (FDO) BLM Planning Area. Source apportionment contributions from new oil and gas emissions on non-Federal lands within all of the Colorado and New Mexico BLM Planning Areas combined was also obtained. Separate source apportionment of AQ/AQRV impacts associated with the 10 mines located within Colorado BLM Planning Areas discussed at the end of Section 3.1.5.

4.1.1 Overview of Source Apportionment Tools

The CAMx OSAT/APCA ozone and PSAT PM source apportionment tools use reactive tracers that are released from each Source Group for which contributions are desired. These reactive tracers operate in parallel to the host photochemical grid model tapping into the models transport, dispersion, chemistry and deposition algorithms. For example, the OSAT/APCA ozone source apportionment tools represents each Source Group's ozone contributions using four reactive tracers that represent the Source Groups VOC emissions (V), NOx emissions (N) and ozone attributed to the Source Group that is formed under more VOC-limited (O3V) and NOx-limited (O3N) conditions. At each time step and in each grid cell, ozone formed is allocated to Source Groups based on the Source Groups relative contribution of VOC or NOx emissions to the total VOC or NOx concentrations after determination of whether ozone formation is more VOC-limited or NOx-limited. The APCA ozone source apportionment tool differs from OSAT in that it recognizes that some precursor emissions are not controllable so redirects ozone formed to the controllable Source Group. For example, when ozone is formed under VOC-limited conditions due to the interaction between biogenic VOC and anthropogenic NOx emissions, a case OSAT would assign the ozone formed to the biogenic emissions Source Group, APCA redirects the ozone formed to the anthropogenic emissions Source Group recognizing that biogenic VOC emissions are not controllable and without the anthropogenic NOx the ozone would not have been generated. In a CAMx APCA source apportionment run, the first Source Category specified in the run is assumed to be the uncontrollable Source Group (typically natural emissions) and ozone will only be allocated to natural emissions when it is due to natural VOC and NOx emissions interacting with each other (e.g., ozone formed due to reactions between biogenic VOC and biogenic NOx).

For the CAMx PSAT PM source apportionment tools there are several families of PM source apportionment tracers that can be run separately or together that track the different components of PM. Each of these families has a different number of reactive tracers to track the pathway from the PM precursor emissions to the ultimate PM compounds. The five different families of PSAT source apportionment are as follows (number of tracers in parenthesis): Sulfate-SO4 (2); Nitrate/ammonium-NO3/NH4 (7); Primary PM (6); Secondary Organic Aerosol- SOA (20) and Mercury-Hg (3). For CARMMS, we used the SO4, NO3/NH4 and Primary PM PSAT families of tracers so that 15 reactive tracers are needed to track PM contribution for each Source Group. The Hg PSAT family was not used because mercury is not a focus of CARMMS and O&G sources have negligible Hg emissions. There are five SOA precursors treated in CAMx: toluene and xylene (aromatics), isoprene, terpene and sesquiterpene. O&G VOC emissions are dominated by light VOCs that do not form any SOA. We examined the speciation of the O&G emissions and found the five VOC species that are SOA precursors account for ~0.1 percent of the O&G VOC emissions. Thus, O&G emission VOCs would have a negligible contribution to SOA so the SOA family of PSAT source apportionment tracers was not used.

4.1.2 CARMMS Source Apportionment Configuration

The APCA version of the OSAT and the SO4, NO3/NH4 and Primary PM (i.e., no SOA) families of PSAT source apportionment was used to track the AQ/AQRV contributions of oil and gas (O&G) development on Federal lands in 14 separate BLM Planning Areas for the 2021 High Development Scenario using the 2008 4 km modeling database. The 14 BLM Planning Areas where separate AQ/AQRV impacts due to new O&G development on Federal lands were obtained are shown in Figure 4-1. In total, the 2021 High Development Scenario CAMx source apportionment modeling tracked AQ/AQRV contributions for 20 separate Source Categories in the order listed in Table 4-1. Because the APCA version of OSAT is being used, the first Source Category has to be natural emissions. The 2nd through 15th Source Categories correspond to new O&G emissions on Federal lands within the 13 Colorado BLM planning areas and the Mancos Shale development area within the New Mexico BLM Farmington District Office lands ("the 14 BLM Planning Areas"). The 16th Source Category is the combined emissions from all new O&G within the 14 BLM Planning Areas on non-Federal lands. The 17th and 18th Source Categories are, respectively, existing O&G within the 14 BLM Planning Areas and mining on Federal lands within the 14 BLM Planning Areas[63]. The 19th Source Category is all O&G emissions (existing, new Federal and new non-Federal) outside of the 14 BLM Planning Areas (i.e., the yellow area in Figure 4-1). And the final (20th) Source Category is remaining anthropogenic emissions (e.g., point, mobile and area sources that are not O&G everywhere or mining on Federal lands within the 14 BLM Planning Areas) in the 4 km modeling domain (see Figure 4-2).

[63] There were no mining emissions within the northern New Mexico Mancos Shale development area.

Table 4-1. Ordering of the 20 Source Categories in the CAMx 2021 High Development Scenario source apportionment modeling.

1	Natural emissions (combined biogenic, fires, lightning, sea salt and WBD).
2	Little Snake FO
3	White River FO
4	Colorado River Valley FO (CRVFO)
5	Roan Plateau Planning area portion of CRVFO
6	Grand Junction FO
7	Uncompahgre FO
8	Tres Rios FO
9	Kremmling FO
10	Royal Gorge FO Area#1 (RGFO#1) -- North
11	Pawnee Grasslands portion of RGFO#1
12	RGFO#2 – West-Central/South
13	RGFO#3 – South
14	RGFO#4 – East-Central
15	New Mexico Farmington District
16	Combined New O&G from non-Federal lands within the 14 BLM Planning Areas
17	Combined Existing O&G from 14 BLM Planning Areas
18	Mining from 14 BLM Planning Areas
19	All O&G (existing and new on Federal and non-Federal lands) in 4 km domain outside of the 14 BLM Planning Areas (see yellow region in Figure 1)
20	Remaining anthropogenic emissions (on-road and non-road mobile, point and area sources everywhere in 4 km domain)

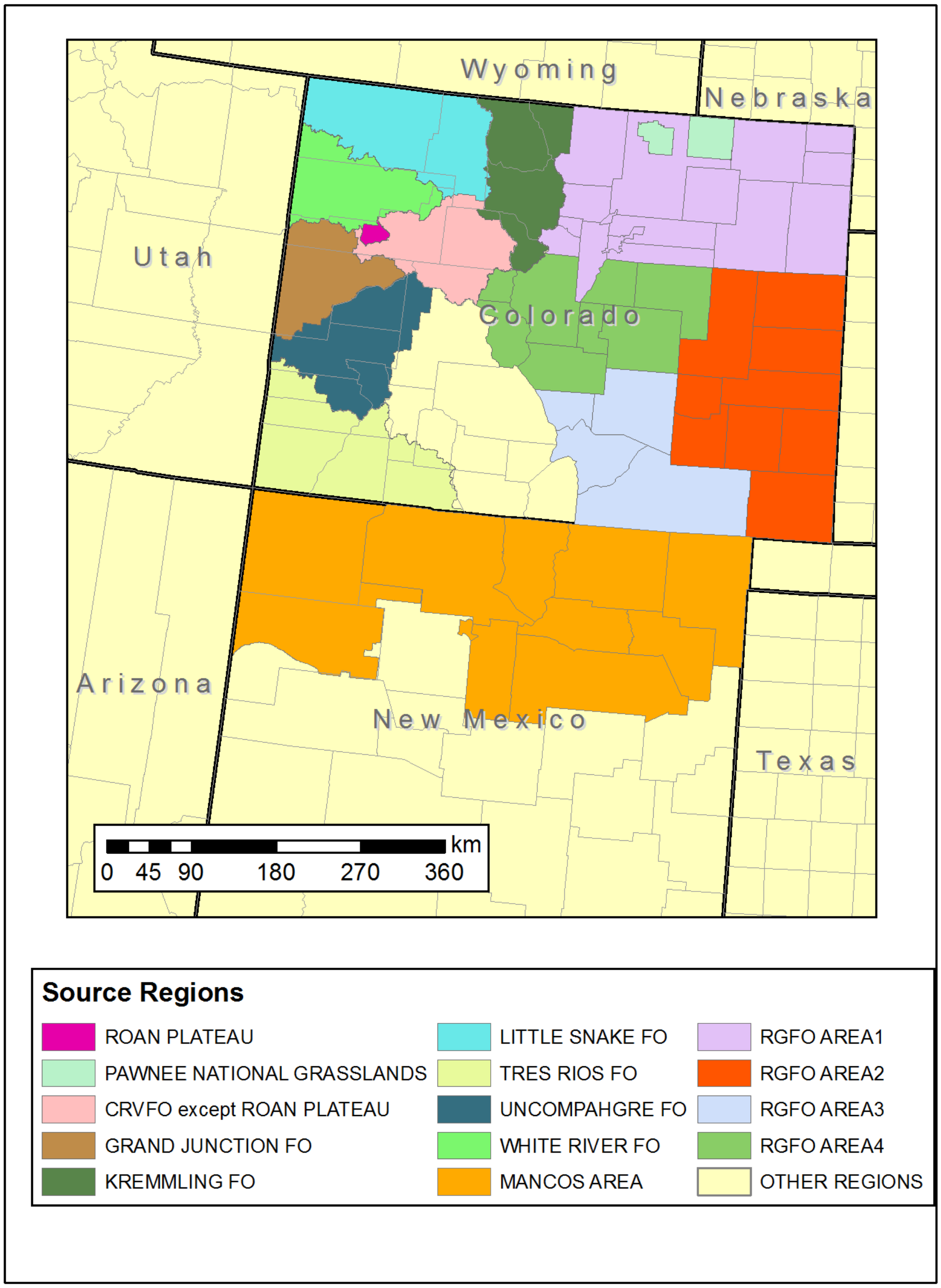


Figure 4-1. 13 Colorado and one New Mexico BLM planning areas (i.e., the 14 BLM Planning Areas) where separate contributions of O&G development on Federal lands was obtain for 2021 High Development Scenario source apportionment modeling.

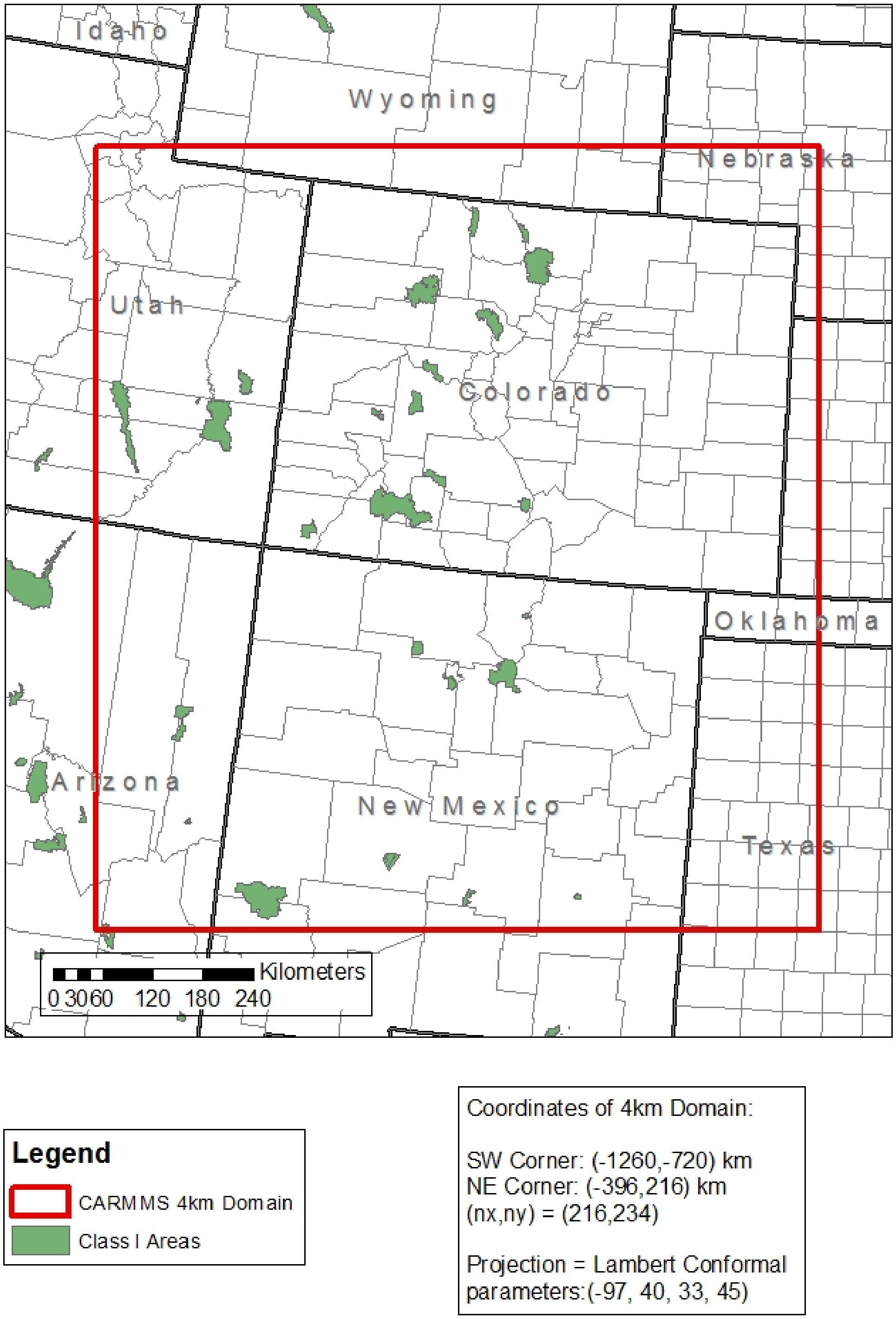


Figure 4-2. 4 km Colorado Air Resource Management Modeling Study (CARMMS) modeling domain.

4.2 Post-Processing of the CAMx 2021 High Development O&G Scenario Source Apportionment Modeling Results

The CAMx total concentrations results were post-processed for comparisons to the applicable ambient air quality standards as listed in Table 4-3. With the exception of ozone, where results will be reported in concentrations units of part per billion by volume (ppb), all concentrations will be reported in units of micrograms per cubic meter ($\mu g/m^3$). Gas-phase species were converted from parts per million (ppm) to $\mu g/m^3$ using the conversion factor recommended in the Colorado Department of Health and Environment (CDPHE) air permit modeling guidance[64]. The incremental AQ and AQRV impacts due to each of the 22 Source Groups listed in Table 4-2 are reported. These 22 Source Groups are labeled A through V consist of the following sources:

(A - N) Federal O&G from each of the 14 BLM Planning Areas as shown in Figure 4-1 and listed as Source Categories No. 2 through 15 in Table 4-1.

(O) Total Federal O&G from the CRVFO that combines the Roan Plateau and non-Roan Plateau portions of the CRVFO.

(P) Total Federal O&G from the RGFO that combines the four RGFO subregions plus the Pawnee Grassland portion of the RGFO.

(Q) Mining on Federal land within the 13 Colorado BLM Planning Areas.

(R) Combined O&G and mining development on Federal lands within all of the 13 Colorado BLM Planning Areas.

(S) Combined new O&G and mining development on Federal lands and new O&G development non-Federal lands within the 13 Colorado BLM Planning Areas.

(T) The Cumulative Emissions scenario that includes new O&G development on Federal and non-Federal lands and mining development on Federal lands within the 13 Colorado BLM Planning areas plus new O&G development for the Mancos Shale area in northern New Mexico.

(U) Emissions from all O&G development throughout the 4 km CARMMS domain (new Federal and non-Federal O&G through the domain plus Federal mining in Colorado).

(V) Natural emissions (biogenic, fires, lightning, WBD and sea salt)

[64] C [ppm] = C [$\mu g/m^3$] / (40.9 x MW), where MW = molecular weight in g/mole. This formula assumes 1 atmosphere pressure and 298 K temperature. http://www.colorado.gov/airquality/permits/guide.pdf

Table 4-2. 22 Source apportionment post-processing Source Groups that separate AQ/AQRV impacts at Class I and sensitive Class II areas will be disclosed.

Processing Source Group	Source Group Name	Source Category No. (See Table 1)
A through N	See Table 1 for names of the new Federal O&G from the 14 BLM Planning Areas Source Categories #2 through #15	Separately #2 - #15
O	Total Colorado River Field Office	#4 and #5
P	Total Royal Gorge Field Office	#10, #11, #12 #13 and #14
Q	Mining from 13 Colorado BLM Planning Areas	#18
R	Combined new Federal O&G and Mining from the 13 Colorado BLM Planning Areas	#2 -#14 and #18
S	Combined new Federal and non-Federal O&G and Mining from 13 Colorado BLM Planning Areas	#2 - #14 plus #16 and #18
T	Cumulative Emissions Scenario – New Federal and non-Federal O&G from 14 BLM Planning Areas plus mining in the 14 BLM Planning Areas	#2 - #16 and #18
U	Combined O&G and Mining in 4 km domain	#2 - #19
V	Natural Emissions	#1

Table 4-3. Applicable National and State Ambient Air Quality Standards and PSD concentration increments (bold indicates units in which standard was defined, conversion to ppm/ppb following CDPHE modeling guidance and with the exception of ozone that will be reported in ppb, all modeled concentrations will be reported in μg/m^3).

Pollutant/Averaging Time	NAAQS	CAAQS[13]	NMAAQS[14]	PSD Class I Increment[1]	PSD Class II Increment[1]
CO					
1-hour[2]	**35 ppm** 40,000 μg/m^3	--	**13.1 ppm** 1,100 μg/m^3	--	--
8-hour[2]	**9 ppm** 10,000 μg/m^3	--	**8.7 ppm** 10,000 μg/m^3	--	--
NO_2					
1-hour[3]	**100 ppb** 188 μg/m^3	--	--	--	--
24-hour	--	--	**0.10 ppm** 1,953 μg/m^3	--	--
Annual[4]	**53 ppb** 100 μg/m^3	--	**0.05 ppm** 98 μg/m^3	2.5 μg/m^3	25 μg/m^3
O_3					
8-hour[5]	**0.075 ppm** 147 μg/m^3	--	--	--	--
PM_{10}					
24-hour[6]	**150 μg/m^3**	--	--	8 μg/m^3	30 μg/m^3
Annual[7]	--	--	--	4 μg/m^3	17 μg/m^3
$PM_{2.5}$					
24-hour[8]	**35 μg/m^3**	--	--	2 μg/m^3	9 μg/m^3
Annual[9]	**12 μg/m^3**	--	--	1 μg/m^3	4 μg/m^3
SO_2					
1-hour[10]	**75 ppb** 196 μg/m^3	--	--		
3-hour[11]	**0.5 ppm** 1,300 μg/m^3	**700 μg/m^3**	--	25 μg/m^3	512 μg/m^3
24-hour[12]	--	--	**0.10 ppm** 262 μg/m^3	5 μg/m^3	91 μg/m^3
Annual[4]	--	--	**0.02 ppm** 52 μg/m^3	2 μg/m^3	20 μg/m^3

1. The PSD demonstrations serve information purposes only and do not constitute a regulatory PSD increment consumption analysis.
2. No more than one exceedance per calendar year; for NMAAQS - No more than one exceedance per consecutive 12 months
3. 98th percentile, averaged over 3 year; for NMAAQS - not to be exceeded more than once over any 12 consecutive months
4. Annual mean not to be exceeded; for NMAAQS - arithmetic average over any four consecutive quarters not to be exceeded
5. Fourth-highest daily maximum 8-hour ozone concentrations in a year, averaged over 3 years
6. Not to be exceeded more than once per calendar year on average over 3 years.
7. 3 year average of the arithmetic means over a calendar year
8. 98th percentile, averaged over 3 years
9. Annual mean, averaged over 3 years, NAAQS promulgated December 14, 2012
10. 99th percentile of daily maximum 1-hour concentrations in a year, averaged over 3 years
11. No more than one exceedance per calendar year (secondary NAAQS) and no more than one exceedance in 12 consecutive months (CAAQS)
12. For areas in New Mexico not within 3.5 miles of the Chino Mines Company
13. http://www.colorado.gov/cs/Satellite/CDPHE-Main/CBON/1251601911433
14. http://www.nmcpr.state.nm.us/nmac/parts/title20/20.002.0003.htm

4.3 Class I and Sensitive Class II Areas for Analysis

The Class I and sensitive Class II areas where air quality and AQRV impacts were calculated within the 4 km CARMMS modeling domains are displayed in Figure 4-3 and listed in Table 4-4. Note that several of the Class I areas are portions of a sensitive Class II area. Figure 4-3 also displays the locations of sensitive lakes in the region where acid neutralizing capacity (ANC) calculations will be made that are listed in Table 4-5.

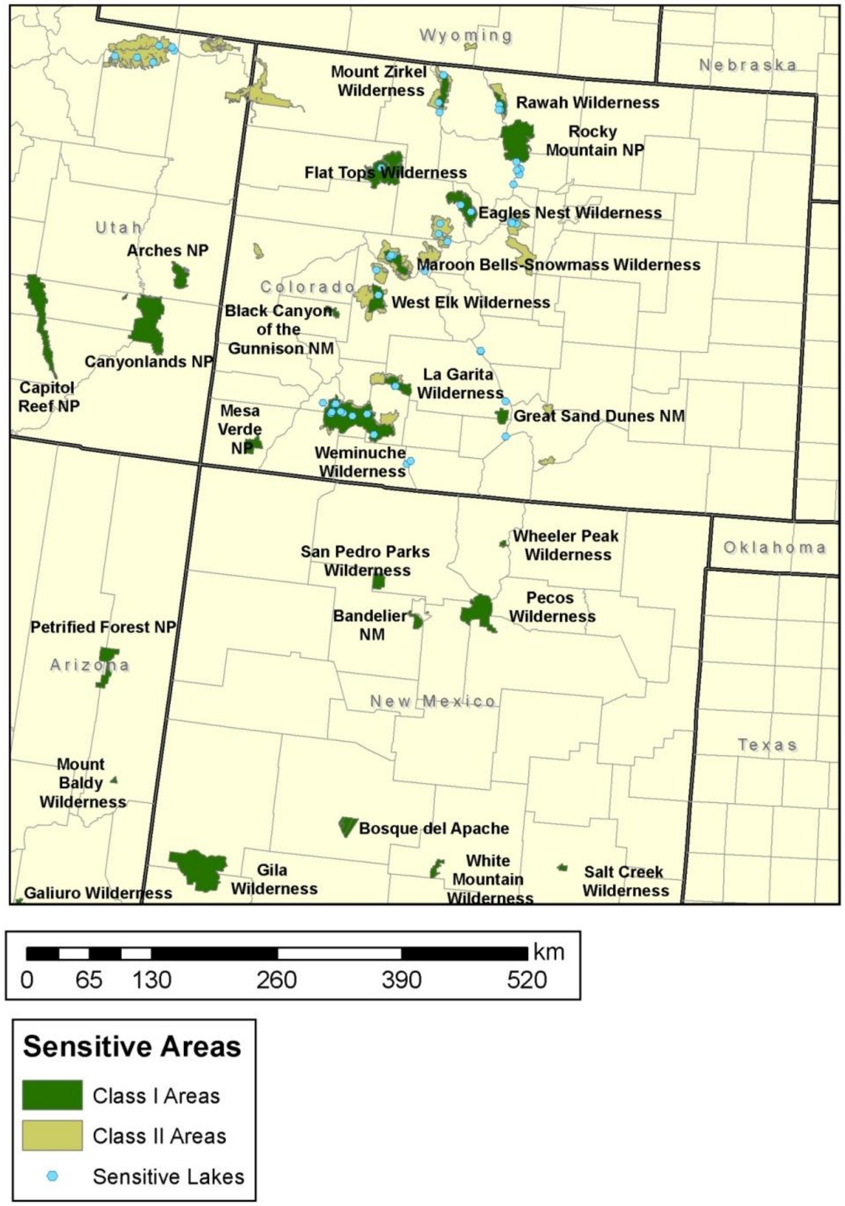


Figure 4-3a. Locations of Class I (dark green) and sensitive Class II (light green) areas where air quality and AQRV impacts were assessed as well as sensitive lakes (blue dots) where ANC calculations will be made (Class I areas are labeled).

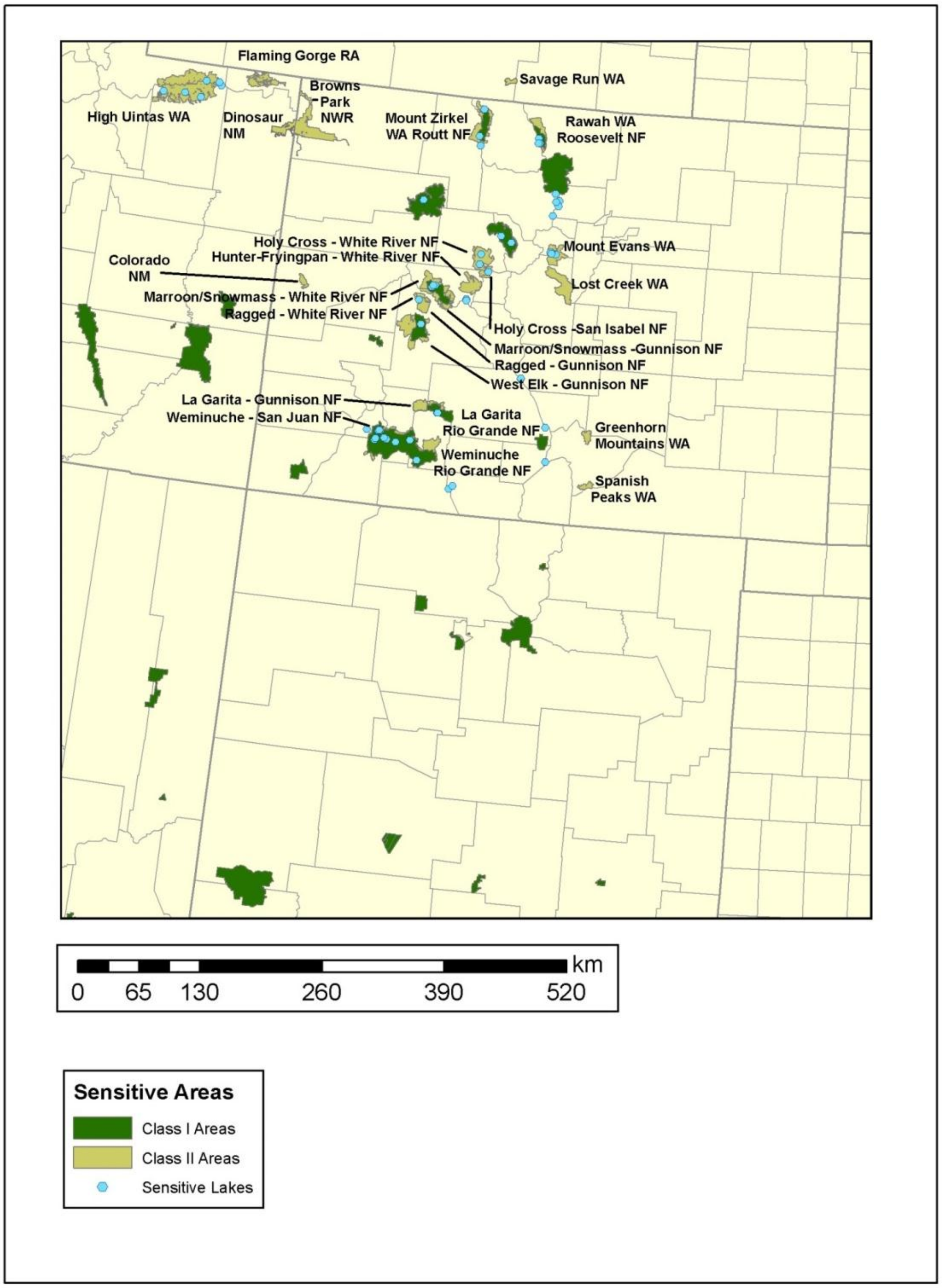


Figure 4-3b. Locations of Class I (dark green) and sensitive Class II (light green) areas where air quality and AQRV impacts were assessed as well as sensitive lakes (blue dots) where ANC calculations will be made (Class II areas are labeled).

Table 4-4a. Class I areas[1] where air quality and AQRV impacts were assessed.

Class I Area Name	State	Administered By
Arches NP	UT	NPS
Bandelier NM	NM	NPS
Black Canyon of the Gunnison NP	CO	NPS
Bosque del Apache (Chupadera Unit) Wilderness	NM	FWS
Bosque del Apache (Indian Well Unit) Wilderness	NM	FWS
Bosque del Apache (Little San Pascual Unit) Wilderness	NM	FWS
Bosque del Apache National Wildlife Refuge	NM	FWS
Canyonlands NP	UT	NPS
Capitol Reef NP	UT	NPS
Eagles Nest Wilderness	CO	FS
Flat Tops Wilderness	CO	FS
Galiuro Wilderness	AZ	FS
Gila Wilderness	NM	FS
Great Sand Dunes NM	CO	NPS
La Garita Wilderness	CO	FS
Maroon Bells-Snowmass Wilderness	CO	FS
Mesa Verde NP	CO	NPS
Mount Baldy Wilderness	AZ	FS
Mount Zirkel Wilderness	CO	FS
Pecos Wilderness	NM	FS
Petrified Forest NP	AZ	NPS
Rawah Wilderness	CO	FS
Rocky Mountain NP	CO	NPS
Salt Creek Wilderness	NM	FWS
San Pedro Parks Wilderness	NM	FS
Weminuche Wilderness	CO	FS
West Elk Wilderness	CO	FS
Wheeler Peak Wilderness	NM	FS
White Mountain Wilderness	NM	FS
Dinosaur NM[1]	UT & CO	NPS

1. The Colorado side of Dinosaur NM is PSD Class I for SO_2

Table 4-4b. Sensitive Class II areas where air quality and AQRV impacts were assessed.

Class II Area Name	State	Administered By
Browns Park NWR	CO	USFWS
Colorado NM	CO	NPS
Dinosaur NM[1]	UT & CO	NPS
Flaming Gorge RA	UT	USFS
Greenhorn Mountains WA	CO	USFS
High Uintas WA	UT	USFS and BLM
Holy Cross Wild/San Isabel NF	CO	USFS
Holy Cross Wild/White River NF	CO	USFS
Hunter-Fryingpan Wild/White River NF	CO	USFS
La Garita Wild/Gunnison NF	CO	USFS
La Garita Wild/Rio Grande NF	CO	USFS
Lost Creek WA	CO	USFS
Maroon Bells-Snowmass Wild/Gunnison NF	CO	USFS
Maroon Bells-Snowmass Wild/White River NF	CO	USFS
Mount Zirkel Wild/Routt NF	CO	USFS
Mount Evans WA	CO	USFS
Raggeds Wild/Gunnison NF	CO	USFS
Raggeds Wild/White River NF	CO	USFS
Rawah Wild/Roosevelt NF	CO	USFS
Savage Run WA	WY	USFS
Spanish Peaks WA	CO	USFS
Weminuche Wild/Rio Grande NF	CO	USFS
Weminuche Wild/San Juan NF	CO	USFS
West Elk Wild/Gunnison NF	CO	USFS
White River NF	CO	USFS

2. The Colorado side of Dinosaur NM is PSD Class I for SO_2

Table 4-5. Sensitive lakes where ANC calculations were made.

Lake	National Forest Name	Wilderness Name
Walk Up Lake	Ashley National Forest	
Tabor Lake	White River National Forest	Collegiate Peaks Wilderness
Brooklyn Lake	White River National Forest	Collegiate Peaks Wilderness
Booth Lake	White River National Forest	Eagles Nest Wilderness
Upper Willow Lake	White River National Forest	Eagles Nest Wilderness
Upper Ned Wilson Lake	White River National Forest	Flat Tops Wilderness
Lower Nwl Packtrail Pothole	White River National Forest	Flat Tops Wilderness
Ned Wilson Lake	White River National Forest	Flat Tops Wilderness
Upper Nwl Packtrail Pothole	White River National Forest	Flat Tops Wilderness
Dean Lake	Ashley National Forest	High Uintas Wilderness
No Name (Utah; Duchesne - 4d2-039)	Ashley National Forest	High Uintas Wilderness
Fish Lake	Wasatch-Cache National Forest	High Uintas Wilderness
Bluebell	ASHLEY NATIONAL FOREST	HIGH UINTAS WILDERNESS
Upper Coffin	Ashley National Forest	High Uintas Wilderness
Blodgett Lake, Colorado	White River National Forest	Holy Cross Wilderness
Upper Turquoise Lake	White River National Forest	Holy Cross Wilderness
Upper West Tennessee Lake	San Isabel National Forest	Holy Cross Wilderness
Blue Lake (Colorado; Boulder - 4e1-040)	Arapaho And Roosevelt National Forests	Indian Peaks Wilderness
No Name (Colorado; Boulder - 4e1-055)	Arapaho And Roosevelt National Forests	Indian Peaks Wilderness
King Lake (Colorado; Grand - 4e1-049)	Arapaho And Roosevelt National Forests	Indian Peaks Wilderness
Crater Lake (Colorado; Grand - 4e1-041)	Arapaho And Roosevelt National Forests	Indian Peaks Wilderness
Upper Lake	Arapaho And Roosevelt National Forests	Indian Peaks Wilderness
Small Lake Above U-Shaped Lake	Rio Grande National Forest	La Garita Wilderness
U-Shaped Lake	Rio Grande National Forest	La Garita Wilderness
Moon Lake (Upper)	White River National Forest	Maroon Bells-Snowmass Wilderness
Avalanche Lake	White River National Forest	Maroon Bells-Snowmass Wilderness
Capitol Lake	White River National Forest	Maroon Bells-Snowmass Wilderness
Upper Middle Beartrack Lake	Arapaho And Roosevelt National Forests	Mount Evans Wilderness
South Lake (Colorado)	Pike And San Isabel National Forests	Mount Evans Wilderness
Abyss Lake	Pike And San Isabel National Forests	Mount Evans Wilderness
North Lake (Colorado)	Pike And San Isabel National Forests	Mount Evans Wilderness
Frozen Lake	Pike And San Isabel National Forests	Mount Evans Wilderness
Seven Lakes (Lg.East)	Medicine Bow-Routt National Forest	Mount Zirkel Wilderness
Summit Lake (Colorado; Jackson - 4e2-060)	Medicine Bow-Routt National Forest	Mount Zirkel Wilderness
Lake Elbert	Medicine Bow-Routt National Forest	Mount Zirkel Wilderness

Lake	National Forest Name	Wilderness Name
Deep Creek Lake, Colorado	Gunnison National Forest	Raggeds Wilderness
Rawah Lake #4	Arapaho And Roosevelt National Forests	Rawah Wilderness
Island Lake	Arapaho And Roosevelt National Forests	Rawah Wilderness
Kelly Lake (Colorado)	Arapaho And Roosevelt National Forests	Rawah Wilderness
Upper Stout Lake	San Isabel National Forest	Sangre De Cristo Wilderness
Upper Little Sand Creek Lake	San Isabel National Forest	Sangre De Cristo Wilderness
Lower Stout Lake	San Isabel National Forest	Sangre De Cristo Wilderness
Crater Lake (Sangre De Cristo)	Rio Grande National Forest	Sangre De Cristo Wilderness
Lake South Of Blue Lakes	San Juan-Rio Grande National Forest	South San Juan Wilderness
Glacier Lake (Colorado)	San Juan-Rio Grande National Forest	South San Juan Wilderness
Little Eldorado Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
White Dome Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
Lake Due South Of Ute Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
Big Eldorado Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
Small Pond Above Trout Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
Upper Sunlight Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
Upper Grizzly Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
West Snowdon Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
Middle Ute Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
Little Granite Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
Lower Sunlight Lake	San Juan-Rio Grande National Forest	Weminuche Wilderness
Four Mile Pothole	San Juan-Rio Grande National Forest	Weminuche Wilderness
South Golden Lake	Grand Mesa, Uncompahgre And Gunnison National Forests	West Elk Wilderness

4.4 Ambient Concentration Analysis using Absolute Modeling Results

Modeled concentrations predicted by the CAMx due to all sources were compared against national and state standards (NAAQS, CAAQS and NMAAQS, see Table 4-3) throughout the 4 km modeling domain. When exceedances of the NAAQS, CAAQS or NMAAQS are estimated, the OSAT/APCA and PSAT source apportionment results was used to determine the contribution of emissions from each of the BLM Planning Areas to determine whether they cause or contribute to the modeled exceedance. The incremental air quality contribution of oil and gas and mining activity to PSD Class I and sensitive Class II areas for each BLM planning area were compared to applicable PSD increments (see Table 4-3). The PSD demonstrations are for information only and are not regulatory PSD Increment consumption analyses, which would be completed as necessary by the relevant state or other agency.

4.5 Ambient Concentration Analysis using Relative Modeling Results

EPA's modeling guidance recommends using the PGM modeling results in a relative fashion when comparing future year modeling results to the ozone and $PM_{2.5}$ NAAQS (EPA, 2007). The relative change in the PGM concentrations between the current and future year simulations are used to scale the observed current year ozone or $PM_{2.5}$ Design Value (DVC) to obtain a projected future year Design Value (DVF). The model derived scaling factors are called Relative Response Factors (RRFs):

$$DVF = DVC \times RRF$$

EPA's PGM modeling guidance provides recommended procedures for calculating DVCs and RRFs (EPA, 2007) that have been implemented in EPA's Modeled Attainment Test Software (MATS[65]; Abt, 2012). The MATS projection tool was used with the CAMx 2008 Base Case and 2021 High Development Scenario modeling results to project future year ozone DVFs that were compared to the NAAQS. MATS also has a capability of projection $PM_{2.5}$ DVFs but there is much less observed $PM_{2.5}$ data in the region so such projections would be extremely limited, so MATS is not used for $PM_{2.5}$. The MATS default settings for making future year ozone and $PM_{2.5}$ projections were used that includes using a current year Design Value (DVC) based on an average of three-years of Design Values (DVs) centered on the Base Case modeling year (2008) and constructing RRFs using at least 10 days of modeling results. As the Base Case year is 2008, then this means using a DVC based on DVs from 2006-2008, 2007-2009 and 2008-2010.

4.6 Visibility Analysis

Visibility impacts were calculated for oil and gas emissions on Federal lands within each BLM Planning Areas as well as for cumulative emissions sources. The approach used the incremental concentrations as quantified by the CAMx PSAT tool simulation of oil and gas and mining activities within each BLM planning area. Changes in light extinction from CAMx model concentration increments due to emissions from oil and gas and other activity emissions were calculated for each day at grid cells that intersect Class I and sensitive Class II areas within the 4 km modeling domain. The FLAG (2010) procedures were used in the incremental BLM planning area-specific visibility assessment analysis.

The visibility evaluation metric used in this analysis is based on the Haze Index which is measured in deciview (dv) units and is defined as follows:

$$HI = 10 \times \ln[b_{ext}/10] .$$

b_{ext} is the atmospheric light extinction measured in inverse megameters (Mm^{-1}) and is calculated primarily from atmospheric concentrations of particulates. A more intuitive measure of haze is visual range (VR), which is defined as the distance at which a large black object just disappears from view, and is measured in km. Visual range is related to b_{ext} by the formula VR = 3912 / b_{ext}. Visual range will not be used as a threshold in the analysis, but could be back-calculated from extinction to give a more easily understood metric.

The incremental concentrations due to BLM planning area emissions were added to background concentrations in the extinction equation (b_{ext}) and the difference between the Haze Index with added BLM planning area concentrations to the Haze Index based solely on background concentrations is calculated. This quantity is the change in Haze Index, which is referred to as "delta deciview" (Δdv) :

[65] http://www.epa.gov/ttn/scram/modelingapps_mats.htm

$$\Delta dv = 10 \times \ln[b_{ext(BLM+background)}/10] - 10 \times \ln[b_{ext(background)}/10]$$

$$\Delta dv = 10 \times \ln[b_{ext(BLM+background)}/b_{ext(background)}]$$

Here $b_{ext(BLM+background)}$ refers to atmospheric light extinction due to oil and gas and other activities in each BLM planning area plus background concentrations, and $b_{ext(background)}$ refers to atmospheric light extinction due to background concentrations only.

For each modeled scenario, estimated visibility degradation at the Class I areas and sensitive Class II areas are presented in terms of the number of days that exceed a threshold change in (Δdv), relative to background conditions. In the next section we describe the method for calculating the extinction, b_{ext}.

4.6.1 IMPROVE Reconstructed Mass Extinction Equations

The FLAG (2010) procedures for evaluating visibility impacts at Class I areas use the revised IMPROVE reconstructed mass extinction equation to convert PM species in μgm^{-3} to light extinction (b_{ext}) in inverse megameters (Mm^{-1}) as follows:

$$b_{ext} = b_{SO4} + b_{NO3} + b_{EC} + b_{OCM} + b_{Soil} + b_{PMC} + b_{SeaSalt} + b_{Rayleigh} + b_{NO2}$$

where

$$b_{SO4} = 2.2 \times f_S(RH) \times [\text{Small Sulfate}] + 4.8 \times f_L(RH) \times [\text{Large Sulfate}]$$

$$b_{NO3} = 2.4 \times f_S(RH) \times [\text{Small Nitrate}] + 5.1 \times f_L(RH) \times [\text{Large Nitrate}]$$

$$b_{OCM} = 2.8 \times [\text{Small Organic Mass}] + 6.1 \times [\text{Large Organic Mass}]$$

$$b_{EC} = 10 \times [\text{Elemental Carbon}]$$

$$b_{Soil} = 1 \times [\text{Fine Soil}]$$

$$b_{CM} = 0.6 \times [\text{Coarse Mass}]$$

$$b_{SeaSalt} = 1.7 \times f_{SS}(RH) \times [\text{Sea Salt}]$$

$$b_{Rayleigh} = \text{Rayleigh Scattering (Site-specific)}$$

$$b_{NO2} = 0.33 \times [NO_2\ (ppb)]\ \{\text{or as: } 0.1755 \times [NO_2\ (\mu g/m^3)]\}.$$

f(RH) are relative humidity adjustment factors that account for the fact that sulfate, nitrate and sea salt aerosols are hygroscopic and are more effective at scattering radiation at higher relative humidity. FLAG (2010) recommends using monthly average f(RH) values rather than the hourly averages recommended in the previous FLAG (2000) guidance document in order to moderate the effects of extreme weather events on the visibility results.

The revised IMPROVE equation treats "large sulfate" and "small sulfate" separately because large and small aerosols affect an incoming beam of light differently. However, the IMPROVE measurements do not separately measure large and small sulfate; they measure only the total $PM_{2.5}$ sulfate. Similarly, CAMx writes out a single concentration of particulate sulfate for each grid cell. Part of the definition of the new IMPROVE equation is a procedure for calculating the large and small sulfate contributions based on the magnitude of the model output sulfate concentrations; the procedure is documented in FLAG (2010). The sulfate concentration magnitude is used as a surrogate for distinguishing between large and small sulfate concentrations. For a given grid cell, the large and small sulfate contributions are calculated from the model output sulfate (which is the "Total Sulfate" referred to in the FLAG (2010) guidance) as:

For Total Sulfate < 20 $\mu g/m^3$:

$$[\text{Large Sulfate}] = ([\text{Total Sulfate}] / 20\ \mu g/m^3) \times [\text{Total Sulfate}]$$

For Total Sulfate ≥ 20 $\mu g/m^3$:

$$[\text{Large Sulfate}] = [\text{Total Sulfate}]$$

For all values of Total Sulfate:

$$[\text{Small Sulfate}] = [\text{Total Sulfate}] - [\text{Large Sulfate}]$$

The procedure is identical for nitrate and organic mass. Sulfate, nitrate and organic mass concentrations for the western U.S. are expected to be mainly in the small fraction.

The NO_2 concentration is approximated by using the CAMx NO_X species in the PSAT source apportionment tool. This is a conservative assumption equivalent to saying that all NO_X is composed entirely of NO_2 for the purposes of the visibility calculation. Although sodium and particulate chloride are treated in the CAMx core model, these species are not carried in the CAMx PSAT tool; neglecting sea salt in the visibility calculations in the 4 km CARMMS impact assessment domains does not compromise the accuracy of the analysis as IMPROVE measurements show that sea salt concentrations are extremely small in this inland area and there would be no sea salt associated with any of the BLM emissions.

Predicted daily average modeled concentrations due to each BLM planning area for grid cells containing Class I and sensitive Class II area receptors were processed using the revised IMPROVE reconstructed mass extinction equation FLAG (2010) to obtain changes in b_{ext} at each sensitive receptor area that are converted to deciview and reported.

The FLAG (2010) method was used to estimate the visibility impacts from each Colorado and northern New Mexico BLM Planning Area. This method used the revised IMPROVE equation together with annual average natural conditions (see Table 6 in FLAG, 2010) and monthly relative humidity factors for each Class I area (see Tables 7-9 in FLAG, 2010). The Δdv was calculated for each grid cell that overlaps a Class I or sensitive Class II area for each day of the annual CAMx run. The highest Δdv across all grid cells overlapping a Class I or sensitive Class II area will be selected to represent the daily value at that area. Visibility impacts due to emissions from BLM Planning Areas that are more than 0.5 dv will be reported.

4.6.2 Cumulative Visibility

The cumulative visibility impacts due to the development of oil and gas and other (e.g., mining) activities on all BLM Planning Areas were assessed following the recommendations from the FWS and NPS that was outlined in their February 10, 2012 letter to the Wyoming Department of Environmental Quality on recommended cumulative visibility method for the Continental Divide-Creston gas infill development EIS (FWS and NPS, 2012) and subsequent conversations with the FLMs. This approach is based on an abbreviated regional haze rule method that estimates the future year visibility at Class I and sensitive Class II areas for the average of the Worst 20% (W20%) and Best 20% (B20%) visibility days with and without the effects of the cumulative emissions on visibility impairment. The cumulative visibility impacts used CAMx model output from the 2008 Base Case and 2021 High Development Scenario in conjunction with monitoring data to produce cumulative visibility impacts at each Class I area in the CARMMS domain. EPA's Modeled Attainment Test Software (MATS[66]) was used to make the 2021 visibility projections for the W20% and B20% days. Cumulative visibility assessments were not made for the sensitive Class II areas since MATS does not include observed data for those areas. The basic steps in the recommended cumulative visibility method are as follows (FES and NPS, 2012):

1. Calculate the observed average 2008 current year cumulative visibility impact using the Haze Index (HI, in deciviews) at each Class I or associated sensitive Class II area to determine the 20% of days with the worst and 20% of days with the best visibility. The intent is to incorporate 5 years of monitoring data surrounding the 2008 Base Case year, which would include 2006-2010. MATS uses the IMPROVE data associate with each Class I area and modeling results at the location of the IMPROVE monitoring site will be used.

2. Estimate the relative response factors (RRFs) for each component of $PM_{2.5}$ and for coarse mass (CM) corresponding to the new IMPROVE visibility algorithm using the CAMx 2008 and 2021 model output.

3. Using the RRFs and ambient data, calculate 2021 future-year daily concentration data for the B20% and W20% days using the CAMx 2008 Base Case and 2021 standard model concentration estimates and PSAT source apportionment modeling results two ways:

    a. <u>2021 Base Case</u>: Use total 2021 High Development Scenario CAMx concentration results due to all emissions;

    b. <u>2021 No Cumulative Emissions</u>: Use PSAT source apportionment results to eliminate contributions of PM concentrations associated with combined emission scenarios corresponding to Source Groups R,S,T and U in Table 4-2.

4. Use the information in 3. to calculate the average 2021 visibility for the 20% Best and 20% Worst visibility days and the 2021 emissions.

5. Assess the average differences in cumulative visibility impacts for the four combined scenarios and also compare with the current observed Baseline visibility conditions.

[66] http://www.epa.gov/ttn/scram/modelingapps_mats.htm

4.7 Sulfur and Nitrogen Deposition

CAMx-predicted wet and dry fluxes of sulfur- and nitrogen-containing species were processed to estimate total annual sulfur (S) and nitrogen (N) deposition values at each Class I and sensitive Class II area and at each acid sensitive lake. The maximum annual S and N deposition values from any grid cell that intersects a Class I or sensitive Class II receptor area was used to represent deposition for that area, in addition to the average annual deposition values of all grid cells that intersect a Class I area and identified grid cells for a sensitive Class II receptor area. Maximum and average predicted S and N deposition impacts were estimated separately for each BLM planning area and together across all BLM planning areas.

Nitrogen deposition impacts were calculated by taking the sum of the nitrogen contained in the fluxes of all nitrogen species modeled by CAMx PSAT source apportionment tool. CAMx species used in the nitrogen deposition flux calculation are: reactive gaseous nitrate species, RGN (NO, NO_2, NO_3 radical, HONO, N_2O_5), TPN (PAN, PANX, PNA), organic nitrates (NTR), particulate nitrate formed from primary emissions plus secondarily formed particulate nitrate (NO_3), gaseous nitric acid (HNO_3), gaseous ammonia (NH_3) and particulate ammonium (NH_4). CAMx species used in the sulfur deposition calculation are primarily sulfur dioxide emissions (SO_2) and particulate sulfate ion from primary emissions plus secondarily formed sulfate (SO_4).

FLAG (2010) recommends that applicable sources assess impacts of nitrogen and sulfur deposition at Class I areas. This guidance recognizes the importance of establishing critical deposition loading values ("critical loads") for each specific Class I area as these critical loads are completely dependent on local atmospheric, aquatic and terrestrial conditions and chemistry. Critical load thresholds are essentially a level of atmospheric pollutant deposition below which negative ecosystem effects are not likely to occur. FLAG (2010) does not include any critical load levels for specific Class I areas and refers to site-specific critical load information on FLM websites for each area of concern. This guidance does, however recommend the use of deposition analysis thresholds (DATs[67]) developed by the National Park Service and the Fish and Wildlife Service. The DATs represent screening level values for nitrogen and sulfur deposition from each BLM planning area emission sources below which estimated impacts are considered negligible. The DAT established for both nitrogen and sulfur in western Class I areas is 0.005 kilograms per hectare per year (kg/ha/yr). As a screening analysis, results for oil and gas and mining activities for each BLM planning area were separately compared to the DATs.

In addition to the screening level analysis, cumulative modeled results will be compared to critical load thresholds to assess total deposition impacts. Deposition results will be compared to critical load thresholds established for the Rocky Mountain region. Critical load thresholds published by Fox et al. (Fox 1989) established pollutant loadings for total nitrogen of 3-5 kilograms per hectare per year (kg/ha/yr) and for total sulfur of 5 kg/ha/yr for Bob Marshall Wilderness Area in Montana and Bridger Wilderness Area in Wyoming. If current deposition of N or S is > 3 kg/ha/yr, or applicable critical loads values or other scientific information is available that suggests the ecosystem is being harmed by current deposition levels, and the oil and gas and mining activity contribution from an individual BLM planning area to deposition is above the DAT screening levels, the impact to the ecosystem can range from moderate to

[67] http://www.nature.nps.gov/air/Pubs/pdf/flag/nsDATGuidance.pdf

major depending on the existing conditions. Research conducted by Baron (2006) using hindcasting of diatom communities suggests 1.5 kg/ha/yr as a critical loading value for wet nitrogen deposition for high elevation lakes in Rocky Mountain National Park, Colorado. Recent research conducted by Saros et al. (2010) using fossil diatom assemblages suggest that a critical load value of 1.4 kg/ha/yr for wet nitrogen is applicable to the eastern Sierra Nevada and Greater Yellowstone ecosystems. Cumulative N and S deposition impacts will be compared to the following critical load values: 1.5 kg/ha/yr for total N deposition; and 3 kg/ha/yr for total S deposition. For N and S, both the average deposition as well as the maximum deposition will be reported, although only the maximum deposition will be compared with the applicable level of concern.

4.8 Acid Neutralizing Capacity

In addition to calculation of total deposition fluxes, an additional analysis was performed to assess the change in water chemistry associated with atmospheric deposition from BLM oil and gas and mining activities and cumulative sources for each of the sensitive lakes listed in Table 4-5. This analysis assesses the change in the acid neutralizing capacity (ANC) of sensitive lakes. An estimate of potential changes in ANC was made by following the procedure developed by the USFS Rocky Mountain Region (USFS, 2000). Predicted changes in ANC are compared with the threshold (10 percent change in ANC for lakes with background ANC values greater than 25 micro equivalents per liter [µeq/L], and no more than a 1 µeq/L change in ANC for lakes with background ANC values equal to or less than 25 µeq/L). A list of sensitive lakes was obtained from the USFS (Table 4-5). The most recent lake chemistry background ANC data was obtained from the VIEWS website for each of the sensitive lakes in the 4 km CARMMS modeling domain.

5.0 ACRONYMS

ACHD	Allegheny County Health Department
AES	Applied Envirosolutions
AMET	Atmospheric Model Evaluation Tool
APCA	Anthropogenic Precursor Culpability Assessment
APU	Auxiliary Power Units
ARMS	Air Resource Management Study
AQ	Air Quality
AQRV	Air Quality Related Value
AQS	Air Quality System
BC	Boundary Condition
BLM	Bureau of Land Management
CAFOS	Concentrated Animal Feeding Operations
CAMD	Clean Air Markets Division
CAMx	Comprehensive Air-quality Model with extensions
CARMMS	Colorado Air Resource Management Modeling Study
CASTNet	Clean Air Status and Trends Network
CAVR	Clean Air Visibility Rule
CB05	Carbon Bond mechanism version 5
CD-C	Continental Divide-Creston
CDPHE	Colorado Department of Health and Environment
CEM	Continuous Emissions Monitor
CENRAP	Central Regional Air Planning Association
CMAQ	Community Multiscale Air Quality modeling system
CMU	Carnegie Mellon University
ConCEPT	Consolidated Community Emissions Processing Tool
CONUS	Continental United States
COSO	BLM Colorado State Office
CPC	Center for Prediction of Climate
CSAPR	Cross State Air Pollution Rule
CSN	Chemical Speciation Network
DDM	Decoupled Direct Method
DEASCO3	Deterministic and Empirical Assessment of Smoke's Contribution to Ozone
ECA	Emissions Control Area
EGU	Electrical Generating Units
EIS	Environmental Impact Statement
EM	Emissions Model
EMS	Emissions Modeling System
EPA	Environmental Protection Agency
EPS	Emissions Processing System
ERG	Eastern Research Group
ESRL	Earth Systems Research Laboratory
FB	Fractional Bias
FE	Fractional Error
FFO	New Mexico BLM Farmington Field Office
FINN	Fire Inventory from NCAR
FLM	Federal Land Manager
FRM	Federal Reference Method
FWS	Fish and Wildlife Service

GCM	Global Chemistry Model
GEOS-Chem	Goddard Earth Observing System (GEOS) global chemistry model
GJFO	Colorado BLM Grand Junction Field Office
GSE	Ground Support Equipment
IAD	Impact Assessment Domain
IMPROVE	Interagency Monitoring of Protected Visual Environments
IMWD	Inter-Mountains West Processing Domain
IPAMS	Independent Petroleum Association of the Mountain States
JSFP	Joint Science Fire Program
LCP	Lambert Conformal Projection
LTO	Landing and Takeoff Operations
LSM	Land Surface Model
MADIS	Meteorological Assimilation Data Ingest System
MATS	Modeled Attainment Test Software
MEGAN	Model of Emissions of Gases and Aerosols in Nature
MM	Meteorological Model
MM5	Version 5 of the Mesoscale Model
MNGE	Mean Normalized Gross Error
MNB	Mean Normalized Bias
MOVES	Motor Vehicle Emissions Simulator
MOZART	Model for Ozone And Related chemical Tracers
NAAQS	National Ambient Air Quality Standard
NADP	National Acid Deposition Program
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NDBC	National Data Buoy Center
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NMB	Normalized Mean Bias
NME	Normalized Mean Error
NMIM	National Mobile Inventory Model
NMSO	BLM New Mexico State Office
NOAA	National Oceanic and Atmospheric Administration
NPRI	National Pollutant Release Inventory
NPS	National Park Service
NSPS	New Source Performance Standard
O&G	Oil and Gas
OA	Organic Aerosol
OSAT	Ozone Source Apportionment Technology
PAVE	Package for Analysis and Visualization
PBL	Planetary Boundary Layer
PGM	Photochemical Grid Model
PiG	Plume-in-Grid
PM	Particulate Matter
PPM	Piecewise Parabolic Method
PSAT	Particulate Source Apportionment Technology
QA	Quality Assurance
QC	Quality Control
RAQC	Regional Air Quality Council
RGFO	Colorado BLM Royal Gorge Field Office
RMC	Regional Modeling Center

RMNP	Rocky Mountain National Park
RMP	Resource Management Plan
ROMANS	Rocky Mountain Atmospheric Nitrogen and Sulfur Study
SCC	Source Classification Code
SIP	State Implementation Plan
SMOKE	Sparse Matrix Kernel Emissions modeling system
SOA	Secondary Organic Aerosol
TCEQ	Texas Commission on Environmental Quality
UAM	Urban Airshed Model
UCR	University of California at Riverside
UFO	Colorado BLM Uncompahgre Field Office
UNC	University of North Carolina
UPA	Unpaired Peak Accuracy
USFS	United States Forest Service
USFS-PG	USFS Pawnee Grasslands
UTSO	BLM Utah State Office
VERDI	Visualization Environment for Rich Data Interpretation
VISTAS	Visibility Improvements for States and Tribal Associations in the Southeast
VMT	Vehicle Miles Traveled
WBD	Wind Blown Dust model
WEA	Western Energy Alliance
WESTUS	Western United States
WRAP	Western Regional Air Partnership
WGA	Western Governors’ Association
WRF	Weather Research Forecasting model

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